REMOVABLE ROUNDED MIDSOLE STRUCTURES AND CHAMBERS WITH COMPUTER PROCESSOR-CONTROLLED VARIABLE PRESSURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to footwear such as a shoe, including an athletic shoe, with a shoe sole, including at least one non-orthotic removable insert formed by a midsole portion. The removable midsole portion is inserted

5 into the foot opening of the shoe upper, the sides of which hold it in position, as may the bottom sole or other portion of the midsole. The shoe sole includes a concavely rounded side or underneath portion, which may be formed in part by the removable midsole portion. The removable midsole portion may extend the length of the shoe sole or may form only a part of the shoe sole and can

10 incorporate cushioning or structural compartments or components. The removable midsole portion provides the capability to permit replacement of midsole material which has degraded or has worn out in order to maintain optimal characteristics of the shoe sole. Also, the removable midsole portion allows customization for the individual wearer to provide tailored cushioning or support

15 characteristics.

The invention further relates to a shoe sole which includes at least one non-orthotic removable midsole insert, at least one chamber or compartment containing a fluid, a flow regulator, a pressure sensor to monitor the compartment

pressure, and a control system capable of automatically adjusting the pressure in the chamber or compartment(s) in response to the impact of the shoe sole with the ground surface, including embodiments which accomplish this function through the use of a computer such as a microprocessor.

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2.   Brief Description of the Prior Art

Many existing athletic shoes are unnecessarily unsafe. Many existing shoe designs seriously impair or disrupt natural human biomechanics. The resulting unnatural foot and ankle motion caused by such shoe designs leads to

10   abnormally high levels of athletic injuries.

Proof of the unnatural effect of many existing shoe designs has come quite unexpectedly from the discovery that, at the extreme end of its normal range of motion, the unshod bare foot is naturally stable and almost impossible to sprain, while a foot shod with a conventional shoe, athletic or otherwise, is

15   artificially unstable and abnormally prone to ankle sprains. Consequently, most ordinary ankle sprains must be viewed as largely an unnatural phenomena, even though such ankle sprains are fairly common. Compelling evidence demonstrates that the stability of bare feet is entirely different from, and far superior to, the stability of shod feet.

20   The underlying cause of the nearly universal instability of shoes is a critical but correctable design flaw. That hidden flaw, so deeply ingrained in existing shoe designs, is so extraordinarily fundamental that it has remained unnoticed until now. The flaw is revealed by a novel biomechanical test, one that

may be unprecedented in its extreme simplicity. The test simulates a lateral ankle

sprain while standing stationary. It is easily duplicated and may be independently

verified by anyone in a minute or two without any special equipment or expertise.

The simplicity of the test belies its surprisingly convincing results. It

5   demonstrates an obvious difference in stability between a bare foot and a foot

shod with an athletic shoe, a difference so unexpectedly noticeable that the test

proves beyond doubt that many existing shoes are unstable and thus unsafe.

The broader implications of this discovery are potentially far-reaching.

The same fundamental flaw in existing shoes that is glaringly exposed by the new

10   test also appears to be the major cause of chronic overuse injuries, which are

unusually common in running, as well as other chronic sport injuries. Existing

shoe designs cause the chronic injuries in the same way they cause ankle sprains;

that is, by seriously disrupting natural foot and ankle biomechanics.

The applicant has introduced into the art the concept of a theoretically

15   ideal stability plane as a structural basis for shoe sole designs. That concept, as

implemented into shoes such as street shoes and athletic shoes, is presented in

U.S. Patent Nos. 4,989,349, issued on February 5, 1991; 5,317,819, issued on

June 7, 1994; and 5,544,429, issued on August 13, 1996, as well as in PCT

Application No. PCT/US89/03076 filed on July 14, 1989, and many subsequent

20   U.S. and PCT applications.

The purpose of the theoretically ideal stability plane as described in these

applications is primarily to provide a neutral shoe design that allows for natural

foot and ankle biomechanics without the serious interference from the shoe

design that is inherent in many existing shoes.

Accordingly, it is a general object of one or more embodiments of the invention to elaborate upon the application of the principle of the natural basis for the support, stability and cushioning of the bare foot to shoe designs.

5   It is still another object of one or more embodiments of the invention to provide a shoe having a sole with natural stability which puts the side of the shoe upper under tension in reaction to destabilizing sideways forces on a tilting shoe.

It is still another object of one or more embodiments of the invention to balance the tension force on the side of the shoe upper substantially in

10   equilibrium to neutralize the destabilizing sideways motion by virtue of the tension in the sides of the shoe upper.

It is another object of one or more embodiments of the invention to create a shoe sole with support and cushioning which is provided by shoe sole compartments, filled with a pressure-transmitting medium like liquid, gas, or gel,

15   that are similar in structure to the fat pads of the foot, and which simultaneously provide both firm support and progressive cushioning.

A further object of one or more embodiments of the invention is to elaborate upon the application of the principle of the theoretically ideal stability plane to other shoe structures.

20   A still further object of one or more embodiments of the invention is to provide a shoe having a sole contour which deviates in a constructive way from the theoretically ideal stability plane.

A still further object of one or more embodiments of the invention is to provide a sole contour having a shape naturally rounded to the shape of a human foot, but having a shoe sole thickness which is increased somewhat beyond the thickness specified by the theoretically ideal stability plane, either through most

5   of the contour of the sole, or at pre-selected portions of the sole.

It is yet another object of one or more embodiments of the invention to provide a naturally rounded shoe sole having a thickness which approximates a theoretically ideal stability plane, but which varies toward either a greater or lesser thickness throughout the sole or at pre-selected portions thereof.

10   It is another object of one or more embodiments of the present invention to implement one or more of the foregoing objects by employing a non-orthotic removable midsole portion of the shoe.

It is yet another object of one or more embodiments of the present invention to combine one or more of the foregoing objects with the ability to

15   customize the shoe design for a particular wearer's foot.

It is a still further object of one or more embodiments of the present invention to combine one or more of the foregoing objects with the ability to replace one or more portions of the shoe in order to substitute new portions for worn portions or for the purpose of customizing the shoe design for a particular

20   activity.

These and other objects of the invention will become apparent from the summary and detailed description of the invention which follow, taken with the accompanying drawings.

SUMMARY OF THE INVENTION

In one aspect, the present invention attempts, as closely as possible, to replicate the naturally effective structures of the bare foot that provide stability,

5 support, and cushioning. More specifically, the invention relates to the structure of removable midsole inserts formed from a midsole portion and integrated into shoes such as athletic shoes. The removable midsole inserts of the present invention are non-orthotic. Even more specifically, this invention relates to the provision of a shoe having an anthropomorphic sole including a non-orthotic

10 midsole insert that substantially copies features of the underlying support, stability and cushioning structures of the human foot. Natural stability is provided by balancing the tension force on the side of the upper in substantial equilibrium so that destabilizing sideways motion is neutralized by the tension.

Still more particularly, this invention relates to support and cushioning

15 which is provided by shoe sole compartments filled with a pressure-transmitting medium like liquid, gas, or gel. Unlike similar existing systems, direct physical contact occurs between the upper surface and the lower surface of the compartments, providing firm, stable support. Cushioning is provided by the pressure-transmitting medium progressively causing tension in the flexible and

20 semi-elastic sides of the shoe sole. The compartments providing support and cushioning are similar in structure to the fat pads of the foot, which simultaneously provide both firm support and progressive cushioning.

Directed to achieving the aforementioned objects and to overcoming problems with prior art shoes, a shoe according to one or more embodiments of the invention comprises a sole having at least a portion thereof which is naturally rounded whereby the upper surface of the sole does not provide a substantial

5   unsupported portion that creates a destabilizing torque and the bottom surface does not provide a substantial unnatural pivoting edge.

In another aspect of the invention, the shoe includes a naturally rounded sole structure exhibiting natural deformation which closely parallels the natural deformation of a foot under the same load. The shoe sole is naturally rounded,

10   paralleling the shape of the foot in order to parallel its natural deformation, and made from a material which, when under load and tilting to the side, deforms in a manner which closely parallels that of the foot of its wearer, while retaining nearly the same amount of contact of the shoe sole with the ground as in its upright state under load.

15   In another aspect, one or more embodiments of this invention relate to variations in the structure of such shoes having a sole contour which follows a theoretically ideal stability plane as a basic concept, but which deviates therefrom to provide localized variations in natural stability. This aspect of the invention may be employed to provide variations in natural stability for an individual whose

20   natural foot and ankle biomechanical functioning have been degraded by a lifetime use of flawed existing shoes.

This new invention is a modification of the inventions disclosed and claimed in the applicant's previously mentioned prior patent applications and

develops the application of the concepts disclosed therein to other shoe structures. In this respect, one or more of the features and/or concepts disclosed in the applicant's prior applications may be implemented in the present invention by the provision of a non-orthotic removable midsole portion. Alternatively, one or

5   more of the features and/or concepts of the present invention may be combined with the provision of a removable midsole portion which itself may or may not implement one of the concepts disclosed in the applicant's prior applications. Further, the removable midsole portion of the present invention may be provided as a replacement for worn shoe portions and/or to customize the shoe design for a

10   particular wearer, for a particular activity or both and, as such, may also be combined with one or more of the features or concepts disclosed in applicant's prior applications.

These and other features of the invention will become apparent from the detailed description of the invention which follows.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1-10 and 12-75 represent embodiments similar to those disclosed in applicant's issued U.S. patents and previous applications. Figure 11 illustrates aspects of the concavely rounded removable midsole insert and chambers or

20   bladders with microprocessor controlled variable pressure of the present invention.

Fig. 1 is a perspective view of a prior art conventional athletic shoe to which the present invention is applicable.

Fig. 2 illustrates in a close-up frontal plane cross section of the heel at the ankle joint the typical shoe known in the art, which does not deform as a result of body weight, when tilted sideways on the bottom edge.

Fig. 3 shows, in the same close-up cross section as Fig. 2, a naturally rounded shoe sole design, also tilted sideways.

Fig. 4 shows a rear view of a barefoot heel tilted laterally 20 degrees.

Fig. 5 shows, in a frontal plane cross section at the ankle joint area of the heel, tension stabilized sides applied to a naturally rounded shoe sole.

Fig. 6 shows, in a frontal plane cross section, the Fig. 5 design when tilted to its edge, but undeformed by load.

Fig. 7 shows, in frontal plane cross section at the ankle joint area of the heel, the Fig. 5 design when tilted to its edge and naturally deformed by body weight.

Fig. 8 is a sequential series of frontal plane cross sections of the barefoot heel at the ankle joint area.

Fig. 8A is an unloaded and upright barefoot heel.

Fig. 8B is a heel moderately loaded by full body weight and upright.

Fig. 8C is a heavily loaded heel at peak landing force while running and upright.

Fig. 8D is heavily loaded heel shown tilted out laterally by about 20 degrees, the maximum tilt for the heel.

Fig. 9 shows a sequential series of frontal plane cross sections of a shoe sole design of the heel at the ankle joint area that corresponds exactly to the Fig. 8

series described above.

Fig. 10 shows two perspective views and a close-up view of a part of a

shoe sole with a structure like the fibrous connective tissue of the groups of fat

cells of the human heel.

5   Fig. 10A shows a quartered section of a shoe sole with a structure

comprising elements corresponding to the calcaneus with fat pad chambers below

it.

Fig. 10B shows a horizontal plane close-up of the inner structures of an

individual chamber of a shoe sole.

10   Fig. 10C shows a horizontal section of a shoe sole with a structure

corresponding to the whorl arrangement of fat pad underneath the calcaneus.

Figs. 11A-11C are frontal plane cross-sectional views showing three

different variations of removable midsole inserts in accordance with the present

invention.

15   Fig. 11D is an exploded view of an embodiment of a removable midsole

in accordance with the present invention.

Figs. 11E-11F are cross-sectional views of alternative embodiments of

interlocking interfaces for releasably securing the removable midsole of the

present invention.

20   Fig. 11G is a frontal plane cross-section of a removable midsole formed

with asymmetric side height. Figs. 11H-11J show other frontal plane sections.

Fig. 11K shows a sagittal plane section and Fig. 11L shows a horizontal plane top

view.

Fig. 11M-11O are frontal plane cross-sectional views showing three

variations of midsole inserts with one or more pressure controlled encapsulated

midsole sections and a control system such as a microprocessor.

Fig. 11P is an exploded view of an embodiment of a removable midsole

5   with pressure controlled encapsulated midsole sections and a control system such

as a microprocessor.

INS A D

Figs. 12A-12C show a series of conventional shoe sole cross sections in

the frontal plane at the heel utilizing both sagittal plane and horizontal plane

sipes, and in which some or all of the sipes do not originate from any outer shoe

10   sole surface, but rather are entirely internal

Fig. 12D shows a similar approach as is shown in Figs. 12A-12C applied

to the fully rounded design.

Figs. 13A-13B show, in frontal plane cross section at the heel area, shoe

sole structures similar to those shown in Figs. 5A-B, but in more detail and with

15   the bottom sole extending relatively farther up the side of the midsole.

Fig. 14 shows, in frontal plane cross section at the heel portion of a shoe,

a shoe sole with naturally rounded sides based on a theoretically ideal stability

plane.

Fig. 15 shows, in frontal plane cross section, the most general case of a

20   fully rounded shoe sole that follows the natural contour of the bottom of the foot

as well as its sides, also based on the theoretically ideal stability plane.

Figs. 16A-16C show, in frontal plane cross section at the heel, a quadrant-

sided shoe sole, based on a theoretically ideal stability plane.

Fig. 17 shows a frontal plane cross section at the heel portion of a shoe with naturally rounded sides like those of Fig. 14, wherein a portion of the shoe sole thickness is increased beyond the theoretically ideal stability plane.

Fig. 18 is a view similar to Fig. 17, but of a shoe with fully rounded sides wherein the sole thickness increases with increasing distance from the center line of the ground-contacting portion of the sole.

Fig. 19 is a view similar to Fig. 18 where the fully rounded sole thickness variations are continually increasing on each side.

Fig. 20 is a view similar to Figs. 17-19 wherein the sole thickness varies in diverse sequences.

Fig. 21 is a frontal plane cross section showing a density variation in the midsole.

Fig. 22 is a view similar to Fig. 21 wherein the firmest density material is at the outermost edge of the midsole contour.

Fig. 23 is a view similar to Figs. 21 and 22 showing still another density variation, one which is asymmetrical.

Fig. 24 shows a variation in the thickness of the sole for the quadrant-sided shoe sole embodiment of Figs. 16A-16C which is greater than a theoretically ideal stability plane.

Fig. 25 shows a quadrant-sided embodiment as in Fig. 24 wherein the density of the sole varies.

Fig. 26 shows a bottom sole tread design that provides a similar density variation to that shown in Fig. 23.

Fig. 27 shows embodiments similar to those shown in Figs. 14-16, but wherein a portion of the shoe sole thickness is decreased to less than the theoretically ideal stability plane.

Fig. 28 shows embodiments of the invention with shoe sole sides having thickness' both greater and lesser than the theoretically ideal stability plane.

Fig. 29 is a frontal plane cross-section showing a shoe sole of uniform thickness that conforms to the natural shape of the human foot.

Figs. 30A-30D show a load-bearing flat component of a shoe sole and a naturally rounded side component, as well as a preferred horizontal periphery of the flat load-bearing portion of the shoe sole.

Figs. 31A-31B are diagrammatic sketches showing a rounded side sole design according to the invention with variable heel lift.

Fig. 32 is a side view of a stable rounded shoe according to the invention.

Fig. 33A is a cross-sectional view of the forefoot portion of a shoe sole taken along lines 33A of Figs. 32 and 33D.

Fig. 33B is a cross-sectional view taken along lines 33B of Figs. 32 and 33D.

Fig. 33C is a cross-sectional view of the heel portion taken along lines 33C in Figs. 32 and 33D.

Fig. 33D is a top view of the shoe sole shown in Fig. 32

Figs. 34A-34D are frontal plane cross-sectional views of a shoe sole according to the invention showing a theoretically ideal stability plane and truncations of the sole side contour to reduce shoe bulk.

Figs. 35A-35C show a rounded sole design according to the invention when applied to various tread and cleat patterns.

Fig. 36 is a diagrammatic frontal plane cross-sectional view of static forces acting on the ankle joint and its position relative to a shoe sole according to the invention during normal and extreme inversion and eversion motion.

Fig. 37 is a diagrammatic frontal plane view of a plurality of moment curves of the center of gravity for various degrees of inversion for a shoe sole according to the invention contrasted with comparable motions of conventional shoes.

Fig. 38 shows a design with naturally rounded sides extended to other structural contours underneath the load-bearing foot such as the main longitudinal arch.

Fig. 39 illustrates a fully rounded shoe sole design extended to the bottom of the entire non-load bearing foot.

Fig. 40 shows a fully rounded shoe sole design abbreviated along the sides to only essential structural support and propulsion elements.

Fig. 41 illustrates a street shoe with a correctly rounded sole according to the invention and side edges perpendicular to the ground.

Fig. 42 shows several embodiments wherein the bottom sole includes most or all of the special contours of the designs and retains a flat upper surface.

Fig. 43 is a rear view of a heel of a foot for explaining the use of a stationery sprain simulation test.

Fig. 44 is a rear view of a conventional athletic shoe unstably rotating about an edge of its sole when the shoe sole is tilted to the outside.

Figs. 45A-45C illustrate functionally the principles of natural deformation as applied to the shoe soles of the invention.

5   Fig. 46 shows variations in the relative density of the shoe sole including the shoe insole to maximize an ability of the sole to deform naturally.

Fig. 47 shows a shoe having naturally rounded sides bent inwardly from a conventional design so then when worn the shoe approximates a custom fit.

Fig. 48 shows a shoe sole having a fully rounded design but having sides

10   which are abbreviated to the essential structural stability and propulsion elements and are combined and integrated into discontinuous structural elements underneath the foot that simulate those of the foot.

Fig. 49 shows the theoretically ideal stability plane concept applied to a negative heel shoe sole that is less thick in the heel area than in the rest of the

15   shoe sole, such as a shoe sole comprising a forefoot lift.

Fig. 49A is a cross sectional view of the forefoot portion taken along line 49A of Fig. 49D.

Fig. 49B is a view taken along line 49B of Fig. 49D.

Fig. 49C is a view of the heel along line 49C of Fig. 49D.

20   Fig. 49D is a top view of the shoe sole with a thicker forefoot section shown with cross-hatching.

Figs. 50A-50E show a plurality of side sagittal plane cross sectional views of examples of negative heel sole thickness variations (forefoot lift) to which the

general approach shown in Figs. 49A-49D can be applied.

Fig. 51 shows the use of the theoretically ideal stability plane concept applied to a flat shoe sole with no heel lift by maintaining the same thickness throughout and providing the shoe sole with rounded stability sides abbreviated to 5 only essential structural support elements.

Fig. 51A is a cross sectional view of the forefoot portion taken along line 51A of Fig. 51D.

Fig. 51B is a view taken along line 51B of Fig. 51D.

Fig. 51C is a view taken along the heel along line 51C in Fig. 51D.

10 Fig. 51D is a top view of the shoe sole with sides that are abbreviated to essential structural support elements shown hatched.

Fig. 51E is a sagittal plane cross section of the shoe sole of Fig. 51D.

Fig. 52 shows, in frontal plane cross section at the heel, the use of a high density (d') midsole material on the naturally rounded sides and a low density (d) 15 midsole material everywhere else to reduce side width.

Fig. 53 shows the footprints of the natural barefoot sole and shoe sole.

Fig. 53A shows the foot upright with its sole flat on the ground.

Fig. 53B shows the foot tilted out 20 degrees to about its normal limit.

Fig. 53C shows a shoe sole of the same size when tilted out 20 degrees to 20 the same position as Fig 53B. The right foot and shoe are shown.

Fig. 54 shows footprints like those shown in Figs. 53A and 53B of a right bare foot upright and tilted out 20 degrees, but showing also their actual relative positions to each other as a high arched foot rolls outward from upright to tilted

out 20 degrees.

Fig. 55 shows a shoe sole with a lateral stability sipe in the form of a vertical slit.

Fig. 55A is a top view of a conventional shoe sole with a corresponding outline of the wearer's footprint superimposed on it to identify the position of the lateral stability sipe relative to the wearer's foot.

Fig. 55B is a cross section of the shoe sole with lateral stability sipe.

Fig. 55C is a top view like Fig. 55A, but showing the print of the shoe sole with a lateral stability sipe when it is tilted outward 20 degrees.

Fig. 56 shows a medial stability sipe that is analogous to the lateral sipe, but to provide increased pronation stability. The head of the first metatarsal and the first phalange are included with the heel to form a medial support section.

Fig. 57 shows footprints 37 and 17, like Fig. 54, of a right bare foot upright and tilted out 20 degrees, showing the actual relative positions to each other as a low arched foot rolls outward from upright to tilted out 20 degrees.

Fig. 58A-D show the use of flexible and relatively inelastic fiber in the form of strands, woven or unwoven (such as pressed sheets), embedded in midsole and bottom sole material.

Fig. 59A-D show the use of flexible inelastic fiber or fiber strands, woven or unwoven (such as pressed) to make an embedded capsule shell that surrounds the cushioning compartment 161 containing a pressure-transmitting medium like gas, gel, or liquid.

Fig. 60A-D show the use of embedded flexible inelastic fiber or fiber strands, woven or unwoven, in various embodiments similar those shown in Figs. 58A-D.

Fig. 60E shows a frontal plane cross section of a fibrous capsule shell 191 that directly envelopes the surface of the midsole section 188.

Fig. 61 shows a view of a bottom sole structure 149, but with no side sections.

Fig. 62 shows a similar structure to Fig. 61, but with only the section under the forefoot 126 unglued or not firmly attached, the rest of the bottom sole 149 (or most of it) would be glued or firmly attached.

Fig. 63C compares the footprint made by a conventional shoe 35 with the relative positions of the wearer's right foot sole in the maximum supination position 37a and the maximum pronation position 37b.

Fig. 63D shows an overhead perspective of the actual bone structures of the foot that are indicated in Fig. 63C.

Fig. 64 shows on the right side an upper shoe sole surface of the rounded side that is complementary to the shape of the wearer's foot sole; on the left side Fig. 64 shows an upper surface between complementary and parallel to the flat ground and a lower surface of the rounded shoe sole side that is not in contact with the ground.

Fig. 65 indicates the angular measurements of the rounded shoe sole sides from zero degrees to 180 degrees.

Fig. 66 shows a shoe sole without rounded stability sides.

Figs. 67-68 also shows a shoe sole without rounded stability sides.

Figs. 69A-E show the implications of relative difference in range of motions between forefoot, Midtarsal, and heel areas on the applicant's naturally rounded sides invention.

Fig. 70 shows an invention for a shoe sole that covers the full range of motion of the wearer's right foot sole.

Fig. 71 shows an electronic image of the relative forces present at the different areas of the bare foot sole when at the maximum supination position shown as 37a in Fig. 62; the forces were measured during a standing simulation of the most common ankle spraining position.

Figs. 72G-H show shoe soles with only one or more of the essential stability elements, but which, based on Fig. 71, still represent major stability improvements over existing footwear. All omit changes in the heel area.

Fig. 72G shows a shoe sole combining additional stability corrections 96a, 96b, and 98, supporting the first and fifth metatarsal heads and distal phalange heads.

Fig. 72H shows a shoe sole with symmetrical stability additions 96a and 96b.

Figs. 73A-73D show in close-up sections of the shoe sole various new forms of sipes, including both slits and channels.

Fig. 74 shows, in Figs. 74A-74E, a plurality of side sagittal plane cross-sectional views showing examples of variations in heel lift thickness similar to

those shown in Figs. 50A-E for the forefoot lift.

Fig. 75 shows, in Figs. 75A-75C, a method, known from the prior art, for assembling the midsole shoe sole structure of the present invention.

5 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The present invention relates to the provision of a removable midsole insert or a removable midsole portion in a shoe sole. The removable midsole concept of the present invention is described more fully with reference to Figs. 11A-11P below. The removable midsole or removable midsole sections of the

10 present invention are non-orthotic. The term "non-orthotic" means that the removable midsoles or midsole portions are not corrective, therapeutic, prosthetic, nor are they prescribed by health care professionals.

The removable midsole or midsole portion, can be used in combination with, or to replace, any one or more features of the applicant's prior inventions

15 as shown in the figures of this application. Such use of the removable midsole or midsole portion can also include a combination of features shown in any other figures of the present application. For example, the removable midsole of the present invention may replace all or any portion or portions of the various midsoles, insoles and bottom soles which are shown in the figures of the

20 present application, and may be combined with, or used to implement, one or more of the various other features described in reference to any of these figures in any of these forms.

All reference numerals used in the figures contained herein are defined

as follows:

Ref. No.	Element Description
2	insole
3	attachment point of upper midsole and shoe upper
4	attachment point of bottom sole and shoe upper
5	attachment point of bottom sole and upper midsole
6	attachment point of bottom sole and lower midsole
8	lower surface interface with the upper surface of the bottom sole
9	interface line between encapsulated section and midsole portions
11	lateral stability sipe
12	medial stability sipe
13	interface between insole and shoe upper
14	medial origin of the lateral stability sipe
16	hatched area of decreased area of footprint due to pronation
17	footprint outline when tilted
18	inner footprint outline of low arched foot
19	hatched area of increased area of footprint due to pronation
20	athletic shoe
21	shoe upper
22	conventional shoe sole
23	bottom outside edge of the shoe sole
23a	lever arm
26	stabilizing quadrants
27	human foot
28	rounded shoe sole
28a	rounded stability sides
28b	load bearing shoe sole
29	outer surface of the foot
30	upper surface of the shoe sole
30a	side or inner edge of the shoe sole stability side
30b	upper shoe sole surface which contacts the wearer's foot
31	lower surface of the shoe sole
31a	outer edge of rounded stability sides
31b	lower surface of shoe sole parallel to 30b
32	outside and top edge of the stability side
33	inner edge of the naturally rounded stability side
34	perpendicular sides of the load-bearing shoe sole
35	peripheral extent of the upper surface of sole
36	shoe sole outline
37	foot outline

37a	maximum supination position
37b	maximum pronation position
38	heel lift
39	combined midsole and bottom sole
40	forefoot lift
43	ground
51	theoretically ideal stability plane
51'	half of the theoretically ideal stability plane
53a	top of rounded stability side
60	tread portion
61	cleated portion
62	alternative tread construction
63	surface which the cleat bases are affixed
70	curve of range of side to side motion
71	center of gravity
80	conventional wide heel flare curve
82	narrow rectangle the width of heel curve
85	contour line of areas of shoe sole that are in contact with the ground
86	contour line
86	contour line
87	contour line
88	contour line
89	contour line
92	head of first metatarsal
93	head of fifth distal phalange
94	head of fifth metatarsal
95	base and lateral tuberosity of the calcaneus
96	heads of the metatarsals
96a	stability correction supporting fifth metatarsal and distal phalange heads
96b	stability correction supporting first metatarsal and distal phalange heads
97	base of the fifth metatarsal
98	head of the first distal phalange
98a	stability correction supporting first distal phalange
98a'	stability correction supporting fifth distal phalange
100	straight line replacing indentation at the base of the fifth metatarsal
104	pressure sensing device
108	lateral calcaneal tuberosity
109	main base of the calcaneus
111	flexibility axis
112	flexibility axis
113	flexibility axis
115	center of rotation of radius r + r'
119	center of shoe sole support section

120	pressure sensing circuitry
121	main longitudinal arch (long arch)
122	flexibility axis
123	flexible connecting top layer of sipes
124	flexibility axis
125	base of the calcaneus (heel)
126	metatarsal heads (forefoot)
129	honeycombed portion
145	non-orthotic removable midsole section
147	upper midsole (upper areas of shoe midsole)
148	midsole
149	bottom sole
150	compression force
151	channels with parallel side walls
155a	tension force along the top surface of the shoe sole
155b	mirror image of tension force 155a
158	subcalcaneal fat pad
159	calcaneus
160	bottom sole of the foot
161	cushioning compartment
162	natural crease or upward taper
163	crease or taper in the human foot
164	chambers of matrix of elastic fibrous connective tissue
165	lower surface of the upper midsole
166	upper surface of the bottom sole
167	outer surface of the support structures of the foot
168	upper surface of the foot's bottom sole
169	shank
170	flexible material filling channels (sipes)
180	mini-chambers
181	internal deformation slits (sipes) in the sagittal plane
182	internal deformation slits (sipes) in the horizontal plane
184	encapsulating outer midsole section
185	midsole sides
187	upper midsole section
188	encapsulated midsole section or bladder
189	central wall
191	fibrous capsule shell
192	subdivided cushioning compartments
201	horizontal line through lower most point of upper surface of the shoe sole
206	fluid duct
210	fluid valve
300	control system

Fig. 1 shows a perspective view of a shoe, such as a typical athletic shoe according to the prior art, wherein the athletic shoe 20 includes an upper portion 21 and a sole 22.

5   Fig. 2 illustrates, in a close-up, a cross-section of a typical shoe of existing art (undeformed by body weight) on the ground 43 when tilted on the bottom outside edge 23 of the shoe sole 22, that an inherent stability problem remains in existing shoe designs, even when the abnormal torque producing rigid heel counter and other motion devices are removed. The problem is that the remaining

10   shoe upper 21 (shown in the thickened and darkened line), while providing no lever arm extension, since it is flexible instead of rigid, nonetheless creates unnatural destabilizing torque on the shoe sole. The torque is due to the tension force 155a along the top surface of the shoe sole 22 caused by a compression force 150 (a composite of the force of gravity on the body and a sideways motion

15   force) to the side by the foot 27, due simply to the shoe being tilted to the side, for example. The resulting destabilizing force acts to pull the shoe sole in rotation around a lever arm 23a that is the width of the shoe sole at the edge. Roughly speaking, the force of the foot on the shoe upper pulls the shoe over on its side when the shoe is tilted sideways. The compression force 150 also creates a

20   tension force 155b, which is the mirror image of tension force 155a.

Fig. 3 shows, in a close-up cross section of a naturally rounded design of rounded shoe sole 28 (also shown undeformed by body weight) when tilted on the bottom edge, that the same inherent stability problem remains in the naturally

rounded shoe sole design, though to a reduced degree. The problem is less since

the direction of the force vector 150 along the lower surface of the shoe upper 21

is parallel to the ground 43 at the outer sole edge 32 edge, instead of angled

toward the ground as in a conventional design like that shown in Fig. 2, so the

5   resulting torque produced by a lever arm created by the outer sole edge 32 would

be less, and the rounded shoe sole 28 provides direct structural support when

tilted, unlike conventional designs.

Fig. 4 shows (in a rear view) that, in contrast, the bare foot is naturally

stable because, when deformed by body weight and tilted to its natural lateral

10   limit of about 20 degrees, it does not create any destabilizing torque due to

tension force. Even though tension paralleling that on the shoe upper is created

on the outer surface 29, both the bottom and sides, of the bare foot by the

compression force of weight-bearing, no destabilizing torque is created because

the lower surface under tension (i.e. the foot's bottom sole, shown in the darkened

15   line) is resting directly in contact with the ground. Consequently, there is no

unnatural lever arm artificially created against which to pull. The weight of the

body firmly anchors the outer surface of the sole underneath the foot so that even

considerable pressure against the outer surface 29 of the side of the foot results in

no destabilizing motion. When the foot is tilted, the supporting structures of the

20   foot, like the calcaneus, slide against the side of the strong but flexible outer

surface of the foot and create very substantial pressure on that outer surface at the

sides of the foot. But that pressure is precisely resisted and balanced by tension

along the outer surface of the foot, resulting in a stable equilibrium.

Fig. 5 shows, in cross section of the upright heel deformed by body

weight, the principle of the tension-stabilized sides of the bare foot applied to the

naturally rounded shoe sole design. The same principle can be applied to

conventional shoes, but is not shown. The key change from the existing art of

5   shoes is that the sides of the shoe upper 21 (shown as darkened lines) must wrap

around the outside edges 32 of the rounded shoe sole 28, instead of attaching

underneath the foot to the upper surface 30 of the shoe sole, as is done

conventionally. The shoe upper sides can overlap and be attached to either the

inner (shown on the left) or outer surface (shown on the right) of the bottom sole,

10   since those sides are not unusually load-bearing, as shown. Alternatively, the

bottom sole, optimally thin and tapering as shown, can extend upward around the

outside edges 32 of the shoe sole to overlap and attach to the shoe upper sides

(shown Fig. 5B). Their optimal position coincides with the Theoretically Ideal

Stability Plane, so that the tension force on the shoe sides is transmitted directly

15   all the way down to the bottom surface of the shoe, which anchors it on the

ground with virtually no intervening artificial lever arm. For shoes with only one

sole layer, the attachment of the shoe upper sides should be at or near the lower or

bottom surface of the shoe sole.

The design shown in Fig. 5 is based on a fundamentally different

20   conception: that the shoe upper is integrated into the shoe sole, instead of attached

on top of it, and the shoe sole is treated as a natural extension of the foot sole, not

attached to it separately.

The fabric (or other flexible material, like leather) of the shoe uppers would preferably be non-stretch or relatively so, so as not to be deformed excessively by the tension placed upon its sides when compressed as the foot and shoe tilt. The fabric can be reinforced in areas of particularly high tension, like

5   the essential structural support and propulsion elements defined in the applicant's earlier applications (the base and lateral tuberosity of the calcaneus, the base of the fifth metatarsal, the heads of the metatarsals, and the first distal phalange). The reinforcement can take many forms, such as like that of corners of the jib sail of a racing sailboat or more simple straps. As closely as possible, it should have

10   the same performance characteristics as the heavily callused skin of the sole of an habitually bare foot. Preferably, the relative density of the shoe sole is as described in Figure 46 of the present application with the softest sole density nearest the foot sole, a progression through less soft sole density through the sole, to the firmest and least flexible at the outermost shoe sole layer. This

15   arrangement allows the conforming sides of the shoe sole to avoid providing a rigid destabilizing lever arm.

The change from existing art to provide the tension-stabilized sides shown in Fig. 5 is that the shoe upper is directly integrated functionally with the shoe sole, instead of simply being attached on top of it. The advantage of the tension-

20   stabilized sides design is that it provides natural stability as close to that of the bare foot as possible, and does so economically, with the minimum shoe sole side width possible.

The result is a shoe sole that is naturally stabilized in the same way that the barefoot is stabilized, as seen in Fig. 6, which shows a close-up cross-section of a naturally rounded shoe sole 28 (undeformed by body weight) when tilted to the edge. The same destabilizing force against the side of the shoe shown in Fig.

5   2 is now stably resisted by offsetting tension in the surface of the shoe upper 21 extended down the side of the shoe sole so that it is anchored by the weight of the body when the shoe and foot are tilted.

In order to avoid creating unnatural torque on the shoe sole, the shoe uppers may be joined or bonded only to the bottom sole, not the midsole, so that

10   pressure shown on the side of the shoe upper produces side tension only and not the destabilizing torque from pulling similar to that described in Fig. 2. However, to avoid unnatural torque, the upper areas 147 of the shoe midsole, which form a sharp corner, should be composed of relatively soft midsole material. In this case, bonding the shoe uppers to the midsole would not create very much destabilizing

15   torque. The bottom sole 149 is preferably thin, at least on the stability sides, so that its attachment overlap with the shoe upper sides coincides, as closely as possible, to the Theoretically Ideal Stability Plane, so that force is transmitted by the outer shoe sole surface to the ground.

In summary, the Fig. 5 design is for a shoe construction, including: a shoe

20   upper that is composed of material that is flexible and relatively inelastic at least where the shoe upper contacts the areas of the structural bone elements of the human foot, and a shoe sole that has relatively flexible sides; and at least a portion of the sides of the shoe upper are attached directly to the bottom sole,

while enveloping on the outside the other sole portions of the shoe sole. This construction can either be applied to conventional shoe sole structures or to the applicant's prior shoe sole inventions, such as the naturally rounded shoe sole conforming to the Theoretically Ideal Stability Plane.

5   Fig. 7 shows, in cross-section at the heel, the tension-stabilized sides concept applied to naturally rounded shoe sole 28 when the shoe and foot are tilted out fully and are naturally deformed by body weight (although constant shoe sole thickness is shown undeformed). The figure shows that the shape and stability function of the shoe sole and shoe uppers mirror almost exactly that of

10   the human foot.

        Figs. 8A-8D show the natural cushioning of the human bare foot 27, in cross sections at the heel. Fig. 8A shows the bare heel upright and unloaded, with little pressure on the subcalcaneal fat pad 158, which is evenly distributed between the calcaneus 159, which is the heel bone, and the bottom sole 160 of the

15   foot.

        Fig. 8B shows the bare heel upright but under the moderate pressure of full body weight. The compression of the calcaneus against the subcalcaneal fat pad produces evenly balanced pressure within the subcalcaneal fat pad because it is contained and surrounded by a relatively unstretchable fibrous capsule, the

20   bottom sole of the foot. Underneath the foot, where the bottom sole is in direct contact with the ground, the pressure caused by the calcaneus on the compressed subcalcaneal fat pad is transmitted directly to the ground. Simultaneously, substantial tension is created on the sides of the bottom sole of the foot because of

the surrounding relatively tough fibrous capsule. That combination of bottom pressure and side tension is the foot's natural shock absorption system for support structures like the calcaneus and the other bones of the foot that come in contact with the ground.

5   Of equal functional importance is that lower surface 167 of those support structures of the foot like the calcaneus and other bones make firm contact with the upper surface 168 of the foot's bottom sole underneath, with relatively little uncompressed fat pad intervening. In effect, the support structures of the foot land on the ground and are firmly supported; they are not suspended on top of

10   springy material in a buoyant manner analogous to a water bed or pneumatic tire, as in some existing proprietary shoe sole cushioning systems. This simultaneously firm and yet cushioned support provided by the foot sole must have a significantly beneficial impact on energy efficiency, also called energy return, different from some conventional shoe sole designs which provide shock

15   absorption cushioning during the landing and support phases of locomotion at the expense of firm support during the take-off phase.

The incredible and unique feature of the foot's natural system is that, once the calcaneus is in fairly direct contact with the bottom sole and therefore providing firm support and stability, increased pressure produces a more rigid

20   fibrous capsule that protects the calcaneus and produces greater tension at the sides to absorb shock. So, in a sense, even when the foot's suspension system would seem in a conventional way to have bottomed out under normal body weight pressure, it continues to react with a mechanism to protect and cushion the

foot even under very much more extreme pressure. This is seen in Fig. 8C, which

shows the human heel under the heavy pressure of roughly three times body

weight force of landing during routine running. This can be easily verified: when

one stands barefoot on a hard floor, the heel feels very firmly supported and yet

5   can be lifted and virtually slammed onto the floor with little increase in the

feeling of firmness; the heel simply becomes harder as the pressure increases.

In addition, it should be noted that this system allows the relatively

narrow base of the calcaneus to pivot from side to side freely in normal

pronation/supination motion, without any obstructing torsion on it, despite the

10   very much greater width of compressed foot sole providing protection and

cushioning. This is crucially important in maintaining natural alignment of joints

above the ankle joint such as the knee, hip and back, particularly in the horizontal

plane, so that the entire body is properly adjusted to absorb shock correctly. In

contrast, existing shoe sole designs, which are generally relatively wide to provide

15   stability, produce unnatural frontal plane torsion on the calcaneus, restricting its

natural motion, and causing misalignment of the joints operating above it,

resulting in the overuse injuries unusually common with such shoes. Instead of

flexible sides that harden under tension caused by pressure like that of the foot,

some existing shoe sole designs are forced by lack of other alternatives to use

20   relatively rigid sides in an attempt to provide sufficient stability to offset the

otherwise uncontrollable buoyancy and lack of firm support of air or gel cushions.

Fig. 8D shows the bare foot deformed under full body weight and tilted

laterally to roughly the 20 degree limit of normal movement range. Again it is

clear that the natural system provides both firm lateral support and stability by providing relatively direct contact with the ground, while at the same time providing a cushioning mechanism through side tension and subcalcaneal fat pad pressure.

5   Figs. 9A-9D show, also in cross-sections at the heel, a naturally rounded shoe sole design that parallels as closely as possible the overall natural cushioning and stability system of the barefoot described in Fig. 8, including a cushioning compartment 161 under support structures of the foot containing a pressure-transmitting medium like gas, gel, or liquid, like the subcalcaneal fat pad under 10   the calcaneus and other bones of the foot. Consequently, Figs. 9A-D directly correspond to Figs. 8A-D. The optimal pressure-transmitting medium is that which most closely approximates the fat pads of the foot. Silicone gel is probably most optimal of materials currently readily available, but future improvements are probable. Since it transmits pressure indirectly, in that it compresses in volume 15   under pressure, gas is significantly less optimal. The gas, gel, or liquid, or any other effective material, can be further encapsulated itself, in addition to the sides of the shoe sole, to control leakage and maintain uniformity, as is common conventionally, and can be subdivided into any practical number of encapsulated areas within a compartment, again as is common conventionally. The relative 20   thickness of the cushioning compartment 161 can vary, as can the bottom sole 149 and the upper midsole 147, and can be consistent or differ in various areas of the shoe sole. The optimal relative sizes should be those that approximate most closely those of the average human foot, which suggests both smaller upper and

lower soles and a larger cushioning compartment than shown in Fig. 9. The

cushioning compartments or pads 161 can be placed anywhere from directly

underneath the foot, like an insole, to directly above the bottom sole. Optimally,

the amount of compression created by a given load in any cushioning

5   compartment 161 should be tuned to approximate as closely as possible the

compression under the corresponding fat pad of the foot.

The function of the subcalcaneal fat pad is not met satisfactorily with

existing proprietary cushioning systems, even those featuring gas, gel or liquid as

a pressure transmitting medium. In contrast to those artificial systems, the design

10   shown in Fig. 9 conforms to the natural contour of the foot and to the natural

method of transmitting bottom pressure into side tension in the flexible but

relatively non-stretching (the actual optimal elasticity will require empirical

studies) sides of the shoe sole.

Some existing cushioning systems do not bottom out under moderate

15   loads and rarely if ever do so under extreme loads. Rather, the upper surface of

the cushioning device remains suspended above the lower surface. In contrast,

the design in Fig. 9 provides firm support to foot support structures by providing

for actual contact between the lower surface 165 of the upper midsole 147 and the

upper surface 166 of the bottom sole 149 when fully loaded under moderate body

20   weight pressure, as indicated in Fig. 9B, or under maximum normal peak landing

force during running, as indicated in Fig. 9C, just as the human foot does in Figs.

8B and 8C. The greater the downward force transmitted through the foot to the

shoe, the greater the compression pressure in the cushioning compartment 161

and the greater the resulting tension on the shoe sole sides.

Fig. 9D shows the same shoe sole design when fully loaded and tilted to the natural 20 degree lateral limit, like Fig. 8D. Fig. 9D shows that an added stability benefit of the natural cushioning system for shoe soles is that the effective thickness of the shoe sole is reduced by compression on the side so that the potential destabilizing lever arm represented by the shoe sole thickness is also reduced, and thus foot and ankle stability is increased. Another benefit of the Fig. 9 design is that the upper midsole shoe surface can move in any horizontal direction, either sideways or front to back in order to absorb shearing forces. The shearing motion is controlled by tension in the sides. Note that the right side of Figs. 9A-D is modified to provide a natural crease or upward taper 162, which allows complete side compression without binding or bunching between the upper and lower shoe sole layers 147, 148, and 149. The shoe sole crease 162 parallels exactly a similar crease or taper 163 in the human foot. Further, 201 represents a horizontal line through the lower most point of the upper surface 30 of the shoe sole.

Another possible variation of joining shoe upper to shoe bottom sole is on the right (lateral) side of Figs. 9A-D, which makes use of the fact that it is optimal for the tension absorbing shoe sole sides, whether shoe upper or bottom sole, to coincide with the Theoretically Ideal Stability Plane along the side of the shoe sole beyond that point reached when the shoe is tilted to the foot's natural limit, so that no destabilizing shoe sole lever arm is created when the shoe is tilted fully, as in Fig. 9D. The joint may be moved up slightly so that the fabric side does not

come in contact with the ground, or it may be covered with a coating to provide both traction and fabric protection.

It should be noted that the Fig. 9 design provides a structural basis for the shoe sole to conform very easily to the natural shape of the human foot and to

5   parallel easily the natural deformation flattening of the foot during load-bearing motion on the ground. This is true even if the shoe sole is made conventionally with a flat sole, as long as rigid structures such as heel counters and motion control devices are not used; though not optimal, such a conventional flat shoe made like Fig. 9 would provide the essential features of the invention resulting in

10   significantly improved cushioning and stability. The Fig. 9 design could also be applied to intermediate-shaped shoe soles that neither conform to the flat ground or the naturally rounded foot. In addition, the Fig. 9 design can be applied to the applicant's other designs, such as those described in Figs. 14-28 of the present application.

15   In summary, the Fig. 9 design shows a shoe construction for a shoe, including: a shoe sole with a compartment or compartments under the structural elements of the human foot, including at least the heel; the compartment or compartments contain a pressure-transmitting medium like liquid, gas, or gel; a portion of the upper surface of the shoe sole compartment firmly contacts the

20   lower surface of said compartment during normal load-bearing; and pressure from the load-bearing is transmitted progressively at least in part to the relatively inelastic sides, top and bottom of the shoe sole compartment or compartments, producing tension.

While the Fig. 9 design copies in a simplified way the macro structure of the foot, Figs. 10 A-C focus more on the exact detail of shoe soles modeled after the natural structures of the foot, including at the micro level. Figs. 10A and 10C are perspective views of cross sections of a part of a rounded shoe sole 28 with a

5   structure like the human heel , wherein elements of the shoe sole structure are similar to chambers of a matrix of elastic fibrous connective tissue which hold closely packed fat cells in the foot 164. The chambers in the foot are structured as whorls radiating out from the calcaneus. These fibrous-tissue strands are firmly attached to the undersurface of the calcaneus and extend to the subcutaneous

10   tissues. They are usually in the form of the letter U, with the open end of the U pointing toward the calcaneus.

As the most natural, an approximation of this specific chamber structure would appear to be the most optimal as an accurate model for the structure of the shoe sole cushioning compartments 161. The description of the structure of

15   calcaneal padding provided by Erich Blechschmidt in Foot and Ankle, March, 1982, (translated from the original 1933 article in German) is so detailed and comprehensive that copying the same structure as a model in shoe sole design is not difficult technically, once the crucial connection is made that such copying of this natural system is necessary to overcome inherent weaknesses in the design of

20   existing shoes. Other arrangements and orientations of the whorls are possible, but would probably be less optimal.

Pursuing this nearly exact design analogy, the lower surface 165 of the upper midsole 147 would correspond to the outer surface 167 of the calcaneus

159 and would be the origin of the U shaped whorl chambers 164 noted above.

Fig. 10B shows a close-up of the interior structure of the large chambers of a rounded shoe sole 28 as shown in Figs. 10A and 10C, with mini-chambers 180 similar to mini-chambers in the foot. It is clear from the fine interior

5 structure and compression characteristics of the mini-chambers 180 in the foot that those directly under the calcaneus become very hard quite easily, due to the high local pressure on them and the limited degree of their elasticity, so they are able to provide very firm support to the calcaneus or other bones of the foot sole. By virtue of their being fairly inelastic, the compression forces on those

10 compartments are dissipated to other areas of the network of fat pads under any given support structure of the foot, like the calcaneus. Consequently, if a cushioning compartment 161, such as the compartment under the heel shown in Fig. 9, is subdivided into smaller chambers, like those shown in Fig. 10, then actual contact between the lower surface of the upper midsole 165 and the upper

15 surface of the bottom sole 166 would no longer be required to provide firm support, so long as those compartments and the pressure-transmitting medium contained in them have material characteristics similar to those of the foot, as described above. The use of gas may not be satisfactory in this approach, since its compressibility may not allow adequate firmness.

20 In summary, the Fig. 10 design shows a shoe construction including: a shoe sole with a compartments under the structural elements of the human foot, including at least the heel; the compartments containing a pressure-transmitting medium like liquid, gas, or gel; the compartments having a whorled structure like

that of the fat pads of the human foot sole; load-bearing pressure being transmitted progressively at least in part to the relatively inelastic sides, top and bottom of the shoe sole compartments, producing tension therein; the elasticity of the material of the compartments and the pressure-transmitting medium are such that normal weight-bearing loads produce sufficient tension within the structure of the compartments to provide adequate structural rigidity to allow firm natural support to the foot structural elements, like that provided by the fat pads of the bare foot. That shoe sole construction can have shoe sole compartments that are subdivided into mini-chambers like those of the fat pads of the foot sole.

Since the bare foot that is never shod is protected by very hard calluses (called a "seri boot") which the shod foot lacks, it seems reasonable to infer that natural protection and shock absorption system of the shod foot is adversely affected by its unnaturally undeveloped fibrous capsules (surrounding the subcalcaneal and other fat pads under foot bone support structures). A solution would be to produce a shoe intended for use without socks (i.e. with smooth surfaces above the foot bottom sole) that uses insoles that coincide with the foot bottom sole, including its sides. The upper surface of those insoles, which would be in contact with the bottom sole of the foot (and its sides), would be coarse enough to stimulate the production of natural barefoot calluses. The insoles would be removable and available in different uniform grades of coarseness, as is sandpaper, so that the user can progress from finer grades to coarser grades as his foot soles toughen with use.

Similarly, socks could be produced to serve the same function, with the area of the sock that corresponds to the foot bottom sole (and sides of the bottom sole) made of a material coarse enough to stimulate the production of calluses on the bottom sole of the foot, with different grades of coarseness available, from fine to coarse, corresponding to feet from soft to naturally tough. Using a tube sock design with uniform coarseness, rather than conventional sock design assumed above, would allow the user to rotate the sock on his foot to eliminate any "hot spot" irritation points that might develop. Also, since the toes are most prone to blistering and the heel is most important in shock absorption, the toe area of the sock could be relatively less abrasive than the heel area.

The invention shown in Figures 11A-11C is a removable and re-insertable, non-orthotic midsole section 145. Alternatively, the non-orthotic midsole section 145 can be attached permanently to adjoining portions of the rounded shoe sole 28 after initial insertion using glue or other common forms of attachment. The rounded shoe sole 28 has an upper surface 30 and a lower surface 31 with at least a part of both surfaces being concavely rounded, as viewed in a frontal plane from inside the shoe when in an unloaded and upright condition. Preferably, all or a part of the midsole section 145 can be removable through any practical number of insertion/removal cycles. The removable midsole 145 can also, optionally, include a concavely rounded side, as shown in Fig. 11A, or a concavely rounded underneath portion or be conventionally formed, with other portions of the shoe sole including concave rounding on the side or underneath portion or portions. All or part of the preferred insole 2 can

also be removable or can be integrated into the upper portion of the midsole

section 145.

The removable portion or portions of the midsole section 145 can

include all or part of the heel lift (not shown) of the rounded shoe sole 28, or all

5   or part of the heel lift 38 can be incorporated into the bottom sole 149

permanently, either using bottom sole material, midsole material, or other

suitable material. Heel lift 38 is typically formed from cushioning material

such as the midsole materials described herein and may be integrated with the

upper midsole 147 or midsole 148 or any portion thereof, including the

10   removable midsole section 145.

The removable portion of the midsole section 145 can extend the entire

length of the shoe sole, as shown in Figs. 11K and 11L, or only a part of the

length, such as a heel area as shown in cross-section in Fig. 11G, a midtarsal

area as shown in cross-section in Fig. 11H, a forefoot area as shown in cross-

15   section in Figs. 11I and 11J, or some portion or combination of those areas.

The removable portion and/or midsole section 145 may be fabricated in any

suitable, conventional manner employed for the fabrication of shoe midsoles or

other, similar structures.

The midsole section 145 , as well as other midsole portions of the shoe

20   sole such as the midsole 148 and the upper midsole 147, can be fabricated from

any suitable material such as elastomeric foam materials. Examples of current

art for elastomeric foam materials include polyether urethane, polyester

urethane, polyurethane foams, ethylene vinyl acetate, ethylene vinyl

acetate/polyethylene copolymer, polyester elastomers such as Hytrel®,

fluoroelastomers, chlorinated polyethylene, chlorosulfonated polyethylene,

acrylonitrile rubber, ethylene vinyl acetate/polypropylene copolymers,

polyethylene, polypropylene, neoprene, natural rubber, Dacron® polyester,

5   polyvinyl chloride, thermoplastic rubbers, nitrile rubber, butyl rubber, sulfide

rubber, polyvinyl acetate, methyl rubber, buna N, buna S, polystyrene, ethylene

propylene polymers, polybutadiene, butadiene styrene rubber, and silicone

rubbers. The most preferred elastomeric foam materials in the current art of

shoe sole midsole materials are polyurethanes, ethylene vinyl acetate, ethylene

10   vinyl acetate/polyethylene copolymers, ethylene vinyl acetate/polypropylene

copolymers, neoprene and polyester elastomers. Suitable materials are selected

on the basis of durability, flexibility and resiliency for cushioning the foot,

among other properties.

As shown in Figure 11D, the midsole section 145 itself can incorporate

15   cushioning or structural compartments or components. Figure 11D shows

cushioning compartments or chambers 161 encapsulated in part of midsole

section 145, as well as bottom sole 149, as viewed in a frontal plane cross-

section. Figure 11D is a perspective view to indicate the placement of disks or

capsules of cushioning material. The disks or capsules of cushioning material

20   may be made from any of the midsole materials mentioned above, and

preferably include a flexible, resilient midsole material such as ethyl vinyl

acetate (EVA), that may be softer or firmer than other sole material or may be

provided with special shock absorption, energy efficiency, wear, or stability

characteristics. The disks or capsules may include a gas, gel, liquid or any other suitable cushioning material. The cushioning material may optionally be encapsulated itself using a film made of a suitable material such as polyurethane film. Other similar materials may also be employed. The

5   encapsulation can be used to form the cushioning material into an insertable capsule in a conventional manner. The example shown in Figure 11D shows such cushioning disks 161 located in the heel area and the lateral and medial forefoot areas, proximate to the heads of the first and fifth metatarsal bones of a wearer's foot. The cushioning material, for example disks or compartments

10   161, may form part of the upper surface of the upper portion of the midsole section145 as shown in Fig. 11D. A cushioning compartment or disk 161 can generally be placed anywhere in the removable midsole section 145 or in only a part of the midsole section 145. A part of the cushioning compartment or disk 161 can extend into the outer sole 149 or other sole portion, or, alternatively,

15   one or more compartments or disks 161 may constitute all or substantially all of the midsole section 145. As shown in Figure 11L, cushioning disks or compartments may also be suitably located at other essential support elements like the base of the fifth metatarsal 97, the head of the first distal phalange 98, or the base and lateral tuberosity of the calcaneus 95, among other suitable

20   conventional locations. In addition, structural components like a shank 169 can also be incorporated partially or completely in a midsole section 145, such as in the medial midtarsal area, as shown in Figure 11D, under the main longitudinal arch of a wearer's foot, and/or under the base of the wearer's fifth metatarsal

bone, or other suitable alternative locations.

In one embodiment, the Figure 11D invention can be made of all mass-produced standard size components, rather than custom fit, but can be individually tailored for the right and left shoe with variations in the firmness of

5   the material in compartments 161 for special applications such as sports shoes, golf shoes or other shoes which may require differences between firmness of the left and right shoe sole.

One of the advantages provided by the removable midsole section 145 of the present invention is that it allows replacement of foamed plastic portions

10   of the midsole which degrade quickly with wear, losing their designed level of resilience, with new midsole material as necessary over the life of the shoe to thereby maintain substantially optimal shock absorption and energy return characteristics of the rounded shoe sole 28.

The removable midsole section 145 can also be transferred from one

15   pair of shoes composed generally of shoe uppers and bottom sole like Figure 11C to another pair like Figure 11C, providing cost savings.

Besides using the removable midsole section 145 to replace worn components with new components, the replacement midsole section 145 can provide another advantage of allowing the use of different cushioning or

20   support characteristics in a single shoe or pair of shoes made like Figure 11C, such as firmer or softer portions of the midsole, or thicker or thinner portions of the midsole, or entire midsoles that are firmer, softer, thicker or thinner, either as separate layers or as an integral part of midsole section 145. In this manner,

a single pair of shoes can be customized to provide the desired cushioning or

support characteristics for a particular activity or different levels of activity,

such as running, training or racing shoes. Figure 11D shows an example of

such removable portions of the midsole in the form of disks or capsules 161,

5   but midsole or insole layers or the entire midsole section 145 can be removed

and replaced temporarily or permanently.

Such replacement midsole sections 145 can be made to include density

or firmness variations like those shown in Figures 21-23 and 25. The midsole

density or firmness variations can differ between a right foot shoe and a left

10   foot shoe, such as Figure 21 as a left shoe and Figure 22 as a right shoe,

showing equivalent portions.

Such replacement removable midsole sections 145 can be made to

include thickness variations, including those shown in Figures 17-20, 24, 27, or

28. Combinations of density or firmness variations and thickness variations

15   shown above can also be made in the replacement midsole sections 145.

Replacement removable midsole sections 145 may be held in position at

least in part by enveloping sides of the shoe upper 21 and/or bottom sole 149.

Alternatively, a portion of the midsole material may be fixed in the shoe sole

and extend up the sides to provide support for holding removable midsole

20   sections 145 in place. If the associated rounded shoe sole 28 has one or more of

the abbreviated sides shown in Figure 11L, then the removable midsole section

can also be held in position against relative motion in the sagittal plane by

indentations formed between one or more concavely rounded sides and the

adjacent abbreviations. Combinations of these various embodiments may also be employed.

The removable midsole section 145 has a lower surface interface 8 with the upper surface of the bottom sole 149. The interface 8 would typically remain unglued, to facilitate repeated removal of the midsole sections 145, or could be affixed by a weak glue, like that of self-stick removable paper notes, that does not permanently fix the position of the midsole section 145 in place.

The interface 8 can also be bounded by non-slip or controlled slippage surfaces. The two surfaces which form the interface 8 can have interlocking complementary geometry's as shown, for example, in Figs. 11E-11F, such as mating protrusions and indentations, or the removable midsole section 145 may be held in place by other conventional temporary attachments, such as, for example, Velcro® strips. Conversely, providing no means to restrain slippage between the surfaces of interface 8 may, in some cases, provide additional injury protection. Thus, controlled facilitation of slippage at the interface 8, may be desirable in some instances and can be utilized within the scope of the invention.

The removable midsole section 145 of the present invention may be inserted and removed in the same manner as conventional removable insoles or conventional midsoles, that is, generally in the same manner as the wearer inserts his foot into the shoe. Insertion of the removable midsole section 145 may, in some cases, requiring loosening of the shoe laces or other mechanisms for securing the shoe to a wearer's foot. For example, the midsole section 145

may be inserted into the interior cavity of the shoe upper and affixed to or

abutted against, the top side of the shoe sole. In a particularly preferred

embodiment, a bottom sole 149 is first inserted into the interior cavity of the

shoe upper 21 as indicated by the arrow in Fig. 75A. The bottom sole 149 is

5   inserted into the cavity so that any rounded stability sides 28a are inserted into

and protrude out of corresponding openings in the shoe upper 21. The bottom

sole 149 is then attached to the upper 21, preferably by a stitch that weaves

around the outer perimeter of the openings thereby connecting the shoe upper

21 to the bottom sole 149. In addition, an adhesive can be applied to the

10   surface of the upper 21 which will contact the bottom sole 149 before the

bottom sole 149 is inserted into the upper 21.

     Once the bottom sole 149 is attached, the removable midsole section

145 may then be inserted into the interior cavity of the upper 21 and affixed to

the top side of the bottom sole 149, as shown in Fig. 75C. The midsole section

15   145 can be releasably secured in place by any suitable method, including

mechanical fasteners, adhesives, snap-fit arrangements, reclosable

compartments, interlocking geometry's and other similar structures.

Additionally, the removable midsole section 145 preferably includes

protrusions placed in an abutting relationship with the bottom sole 149 so that

20   the protrusions occupy corresponding recesses in the bottom sole 149.

     Alternatively, the removable midsole section 145 may be glued to affix

the midsole section 145 in place on the bottom sole 149. In such an

embodiment, an adhesive can be used on the bottom side of the midsole section

145 to secure the midsole to the bottom sole 149.

Replacement removable midsole sections 145 with concavely rounded sides that provide support for only a narrow range of sideways motion or with higher concavely rounded sides that provide for a very wide range of sideways

5   motion can be used to adapt the same shoe for different sports, like running or basketball, for which lessor or greater protection against ankle sprains may be considered necessary, as shown in Figure 11G. Different removable midsole sections 145 may also be employed on the left or right side, respectively. Replacement removable midsole sections 145 with higher curved sides that

10   provide for an extra range of motion for sports which tend to encourage pronation-prone wearers on the medial side, or on the lateral side for sports which tend to encourage supination-prone wearers are other potentially beneficial embodiments.

Individual removable midsole sections 145 can be custom made for a

15   specific class of wearer or can be selected by the individual from mass-produced standard sizes with standard variations in the height of the concavely rounded sides, for example.

Figs. 11M-11P show shoe soles with one or more encapsulated midsole sections or chambers such as bladders 188 for containing fluid such as a gas,

20   liquid, gel or other suitable materials, and with a duct, a flow regulator, a sensor, and a control system such as a microcomputer. The existing art is described by U.S. Patent No. 5,813,142 by Demon, issued September 29, 1998 and by the references cited therein.

Figs. 11M-11P also include the inventor's concavely rounded sides as

described elsewhere in this application, such as figs. 11A-11L (and/or

concavely rounded underneath portions). In addition, Figs. 11M-11P show

ducts that communicate between encapsulated midsole sections or

5   chambers/bladders 188 or within portions of the encapsulated midsole sections

or bladders 188. Other suitable conventional embodiments can also be used in

combination with the applicant's concavely rounded portions. Also, Figs. 11N-

11P show removable midsole sections 145. Fig. 11M shows a non-removable

midsole in combination with the pressure controlled bladder or encapsulated

10   section 188 of the invention. The bladders or sections 188 can be any size

relative to the midsole encapsulating them, including replacing the

encapsulating midsole substantially or entirely.

Also, included in the applicant's invention, but not shown, is the use of

a piezo-electric effect controlled by a microprocessor control system to affect

15   the hardness or firmness of the material contained in the encapsulated midsole

section, bladder, or other midsole portion 188. For example, a disk-shaped

midsole or other suitable material section 161, may be controlled by electric

current flow instead of fluid flow, with common electrical components

replacing those described below which are used for conducting and controlling

20   fluid flow under pressure.

Figure 11M shows a shoe sole embodiment with the applicant's

concavely rounded sides invention described in earlier figures, including both

concavely rounded sole inner and outer surfaces, with a bladder or an

encapsulated midsole section 188 in both the medial and lateral sides and in the

middle or underneath portion between the sides. An embodiment with a

bladder or encapsulated midsole section 188 located in only a single side and

the middle portion is also possible, but not shown, as is a an embodiment with a

5 bladder or encapsulated midsole section 188 located in both the medial and

lateral sides without one in the middle portion. Each of the bladders 188 is

connected to an adjacent bladder(s) 188 by a fluid duct 206 passing through a

fluid valve 210, located in midsole section 145, although the location could be

anywhere in a single or multi-layer rounded shoe sole 28. Figure 11M is based

10 on the left side of Figure 13A. In a piezo-electric embodiment using midsole

sections 188, the fluid duct between sections would be replaced by a suitable

wired or wireless connection, not shown. A combination of one or more

bladders 188 with one or more midsole sections is also possible but not shown.

One advantage of the applicant's invention, as shown in the applicant's

15 Fig. 11M, is to provide better lateral or side-to-side stability through the use of

rounded sides, to compensate for excessive pronation or supination, or both,

when standing or during locomotion. The Figure 11M embodiment also shows

a fluid containment system that is fully enclosed and which uses other bladders

188 as reservoirs to provide a unique advantage. The advantage of the Figure

20 11M embodiment is to provide a structural means by which to change the

hardness or firmness of each of the shoe sole sides and of the middle or

underneath sole portion, relative to the hardness or firmness of one or both of

the other sides or sole portion, as seen for example in a frontal plane, as shown,

or in a sagittal plane (not shown).

Although Figure 11M shows communication between each bladder or midsole section 188 within a frontal plane (or sagittal plane), which is a highly effective embodiment, communication might also be between only two adjacent or non-adjacent bladders or midsole sections 188 due to cost, weight, or other design considerations. The operation of the applicant's invention, beyond that described herein with the exceptions specifically indicated, is as is known in the prior art, specifically the Demon '142 patent, the relevant portions of which, such as the disclosure of suitable system and electronic circuitry shown in schematic representations in Figures 2, 6, and 7 of the Demon '142 patent and the pressure sensitive variable capacitor shown in Figure 5, as well as the textual specification associated with those figures, are hereby incorporated by reference.

Each fluid bladder or midsole section 188 may be provided with an associated pressure sensing device that measures the pressure exerted by the user's foot on the fluid bladder or midsole section 188. As the pressure increases above a threshold, a control system opens (perhaps only partially) a flow regulator to allow fluid to escape from the fluid bladder or section 188. Thus, the release of fluid from the fluid bladder or section 188 may be employed to reduce the impact of the user's foot on the ground. Point-pressure under a single bladder 188, for example, can be reduced by a controlled fluid outflow to any other single bladder or any combination of the other bladders.

Preferably, the sole of the shoe is divided into zones which roughly

correspond to the essential structural support and propulsion elements of the

intended wearer's foot, including the base of the calcaneus, the lateral tuberosity

of the calcaneus 95, the heads of the metatarsals 96 (particularly the first and

5   fifth), the base of the fifth metatarsal, the main longitudinal arch (optional), and

the head of the first distal phalange 98. The zones under each individual

element can be merged with adjacent zones, such as a lateral metatarsal head

zone 96e and a medial metatarsal head zone 96d.

The pressure sensing system preferably measures the relative change in

10   pressure in each of the zones. The fluid pressure system thereby reduces the

impact experienced by the user's foot by regulating the escape of a fluid from a

fluid bladder or midsole section 188 located in each zone of the sole. The

control system 300 receives pressure data from the pressure sensing system and

controls the fluid pressure system in accordance with predetermined criteria

15   which can be implemented via electronic circuitry, software or other

conventional means.

The pressure sensing system may include a pressure sensing device 104

disposed in the sole of the shoe at each zone. In a preferred embodiment, the

pressure sensing device 104 is a pressure sensitive variable capacitor which

20   may be formed by a pair of parallel flexible conductive plates disposed on each

side of a compressible dielectric. The dielectric can be made from any suitable

material such as rubber or another suitable elastomer. The outside of the

flexible conductive plates are preferably covered by a flexible sheath (such as

rubber) for added protection.

Since the capacitance of a parallel plate capacitor is inversely proportional to the distance between the plates, compressing the dielectric by applying increasing pressure results in an increase in the capacitance of the

5 pressure sensitive variable capacitor. When the pressure is released, the dielectric expands substantially to its original thickness so that the pressure sensitive variable capacitor returns substantially to its original capacitance. Consequently, the dielectric must have a relatively high compression limit and a high degree of elasticity to provide ideal function under variable loading.

10 The pressure sensing system also includes pressure sensing circuitry 120 which converts the change in pressure detected by the variable capacitor into digital data. Each variable capacitor forms part of a conventional frequency-to-voltage converter (FVC) which outputs a voltage proportional to the capacitance of variable capacitor. An adjustable reference oscillator may be

15 electrically connected to each FVC. The voltage produced by each of the FVCs is provided as an input to a multiplexer which cycles through the channels sequentially connecting the voltage from each FVC to an analog-to-digital (A/D) converter to convert the analog voltages into digital data for transmission to control system 300 via data lines, each of which is connected to control

20 system 300. The control system 300 can control the multiplexer to selectively receive data from each pressure sensing device in any desirable order. These components and circuitry are well known to those skilled and the art and any suitable component or circuitry might be used to perform the same function.

The fluid pressure system selectively reduces the impact of the user's foot in each of the zones. Associated with each pressure sensing device 104 in each zone, and embedded in the shoe sole, is at least one bladder or midsole section 188 which forms part of the fluid pressure system. A fluid duct 206 is connected at its first end to its respective bladder or section 188 and is connected at its other end to a fluid reservoir. In this embodiment, fluid duct 206 connects bladder or midsole section 188 with ambient air, which acts as a fluid reservoir, or, in a different embodiment, with another bladder 188 also acting as a fluid reservoir. A flow regulator, which in this embodiment is a fluid valve 210, is disposed in fluid duct 206 to regulate the flow of fluid through fluid duct 206. Fluid valve 210 is adjustable over a range of openings (i.e., variable metering) to control the flow of fluid exiting bladder or section 188 and may be any suitable conventional valve such as a solenoid valve as in this embodiment.

Control system 300, which preferably includes a programmable microcomputer having conventional RAM and/or ROM, receives information from the pressure sensing system indicative of the relative pressure sensed by each pressure sensing device 104. Control system 300 receives digital data from pressure sensing circuitry 120 proportional to the relative pressure sensed by pressure sensing devices 104. Control system 300 is also in communication with fluid valves 210 to vary the opening of fluid valves 210 and thus control the flow of fluid. As the fluid valves of this embodiment are solenoids (and thus electrically controlled), control system 300 is in electrical communication

with fluid valves 210. An analog electronic control system 300 with other components being analog is also possible.

The preferred programmable microcomputer of control system 300 selects (via a control line) one of the digital-to-analog (D/A) converters to receive data from the microcomputer in order to control fluid valves 210. The selected D/A converter receives the data and produces an analog voltage proportional to the digital data received. The output of each D/A converter remains constant until changed by the microcomputer (which can be accomplished using conventional data latches, which is not shown). The output of each D/A converter is supplied to each of the respective fluid valves 210 to selectively control the size of the opening of fluid valves 210.

Control system 300 also can include a cushioning adjustment control to allow the user to control the level of cushioning response from the shoe. A control device on the shoe can be adjusted by the user to provide adjustments in cushioning ranging from no additional cushioning (fluid valves 210 never open) to maximum cushioning (fluid valves 210 open wide). This is accomplished by scaling the data to be transmitted to the D/A converters (which controls the opening of fluid valves 210) by the amount of desired cushioning as received by control system 300 from the cushioning adjustment control. However, any suitable conventional means of adjusting the cushioning could be used.

An illuminator, such as a conventional light emitting diode (LED), can be mounted to the circuit board that houses the electronics of control system 300 to provide the user with an indication of the state of operation of the

apparatus.

The operation of this embodiment of the present invention is most useful for applications in which the user is either walking or running for an extended period of time during which weight is distributed among the zones of

5   the foot in a cyclical pattern. The system begins by performing an initialization process which is used to set up pressure thresholds for each zone. During initialization, fluid valves 210 are fully closed while the bladders or sections 188 are in their uncompressed state (e.g., before the user puts on the shoes). In this configuration, no fluid, including a gas like air, can escape the bladders or

10 sections 188 regardless of the amount of pressure applied to the bladders or sections 188 by the user's foot. As the user begins to walk or run with the shoes on, control system 300 receives and stores measurements of the change in pressure of each zone from the pressure sensing system. During this period, fluid valves 210 are kept closed.

15 Next, control system 300 computes a threshold pressure for each zone based on the measured pressures for a given number of strides. In this embodiment, the system counts a predetermined number of strides, i.e. ten strides (by counting the number of pressure changes), but another system might simply store data for a given period of time (e.g. twenty seconds). The number

20 of strides are preprogrammed into the microcomputer but might be inputted by the user in other embodiments. Control system 300 then examines the stored pressure data and calculates a threshold pressure for each zone. The calculated threshold pressure, in this embodiment, will be less than the average peak

pressure measured and is in part determined by the ability of the associated

bladder or section 188 to reduce the force of the impact as explained in more

detail below.

After initialization, control system 300 will continue to monitor data

5   from the pressure sensing system and compare the pressure data from each zone

with the pressure threshold of that zone. When control system 300 detects a

measured pressure that is greater than the pressure threshold for that zone,

control system 300 opens the fluid valve 210 (in a manner as discussed above)

associated with that pressure zone to allow fluid to escape from the bladder or

10   section 188 into the fluid reservoir at a controlled rate. In this embodiment, air

escapes from bladder or section 188 through fluid duct 206 (and fluid valve 210

disposed therein) into ambient air. The release of fluid from the bladder or

section 188 allows the bladder or section 188 to deform and thereby lessens the

"push back" of the bladder. The user experiences a "softening" or enhanced

15   cushioning of the sole of the shoe in that zone, which reduces the impact on the

user's foot in that zone.

The size of the opening of fluid valve 210 should allow fluid to escape

the bladder or section 188 in a controlled manner. The fluid should not escape

from bladder or section 188 so quickly that the bladder or section 188 becomes

20   fully deflated (and can therefore supply no additional cushioning) before the

peak of the pressure exerted by the user. However, the fluid must be allowed to

escape from the bladder or section 188 at a high enough rate to provide the

desired cushioning. Factors which will bear on the size of the opening of the

flow regulator include the viscosity of the fluid, the size of the fluid bladder, the

pressure exerted by fluid in the fluid reservoir, the peak pressure exerted and

the length of time such pressure is maintained.

As the user's foot leaves the traveling surface, a fluid like air is forced

5   back into the bladder or section 188 by a reduction in the internal air pressure of

the bladder or section 188 (i.e., a vacuum is created) as the bladder or section

188 returns to its non-compressed size and shape. After control system 300

receives pressure data from the pressure sensing system indicating that no

pressure (or minimal pressure) is being applied to the zones over a

10   predetermined length of time (long enough to indicate that the shoe is not in

contact with the traveling surface and that the bladders or sections 188 have

returned to their non-compressed size and shape), control system 300 again

closes all fluid valves 210 in preparation for the next impact of the user's foot

with the traveling surface.

15   Pressure sensing circuitry 120 and control system 300 are mounted to

the shoe and are powered by a common, conventional battery supply. As

pressure sensing device 104 and the fluid system are generally located in the

sole of the shoe, the described electrical connections are preferably embedded

in the upper and the sole of the shoe.

20   The Figure 11M embodiment can also be modified to omit the

applicant's concavely rounded sides and can be combined with the various

features of any one or more of the other figures included in this application, as

can the features of Figures 11N-11P. Pressure sensing devices 104 are also

shown in Fig. 11M. A control system 300, such as a microprocessor as described above, forms part of the embodiment shown in Figure 11M (and Figures 11N-11O), but is not shown in the frontal plane cross section.

Figure 11N shows the application of the figure 11M concept as described above and implemented in combination with a removable midsole section 145. One significant advantage of this embodiment, besides improved lateral stability, is that the potentially most expensive component of the shoe sole, the removable insert, can be moved to other pairs of shoe upper/bottom soles, whether new or having a different style or function. Separate removable insoles can also be useful in this case, especially in changing from athletic shoes to dress shoes, for function and/or style.

Figure 11N shows a simplified embodiment employing only two bladders or encapsulated sections 188, each of which extends from a concavely rounded side to the central portion. Figure 11N is based on the right side of Figure 13A.

The Figure 11O embodiment is similar to the Figure 11N embodiment, except that only one bladder or encapsulated section 188 is shown, separated centrally by a wall 189 containing a fluid valve communicating between the two separate parts of the section or bladder 188. The angle of the separating wall 189 provides a gradual transition from the pressure of the left compartment to the pressure of the right compartment, but is not required. Other structures may be present within or outside the section or bladder 188 for support or other purposes, as is known in the art.

Figure 11P is a perspective view of the applicant's invention, including

the control system 300, such as a microprocessor, and pressure-sensing circuitry

120, which can be located anywhere in the removable midsole insert 145

shown, in order for the entire unit to be removable as a single piece, with

5   placement in the shank proximate the main longitudinal arch of the wearer's

foot shown in this figure, or alternatively, located elsewhere in the shoe,

potentially with a wired or wireless connection and potentially separate means

of attachment. The heel bladder 188 shown in Fig. 11P is similar to that shown

in Fig. 11O with both lateral and medial chambers.

10   Like Figure 11M, Figures 11N-11P operate in the manner known in the

art as described above, except as otherwise shown or described herein by the

applicant, with the applicant's depicted embodiments being preferred but not

required.

Although not shown, the removable midsole section 145 of the various

15   embodiments shown in figures 11A-11O, can include its own integral upper or

bootie, such as of elastic incorporating stretchable fabric, and its own outer sole

for protection of the midsole and for traction, so that the midsole section 145

can be worn, preferably indoors, without the shoe upper 21 and outer sole 149.

Such a removable midsole section 145 can still be inserted into the Figure 11C

20   upper and sole as described above for outdoor or other rigorous use.

The embodiments shown in Figures 11M-11P can also include the

capability to function sufficiently rapidly to sense an unstable shoe sole

condition such as, for example, that initiating a slip, trip, or fall, and to react to

promote a stable or more stable shoe sole condition to attempt to prevent a fall

or at least attempt to reduce associated injuries, for example, by rapidly

reducing high point pressure in one zone of the shoe sole so that pressures in all

zones are quickly equalized to restore stability of the shoe sole.

5   The removable midsole section 145, for example as shown in Figures

11A-11P, can also be used in combination with, or to implement, one or more

features of any of the applicant's prior inventions shown in the other figures in

this application. Such use can also include a combination of features shown in

any other figures of the present application. For example, the removable

10   midsole section 145 of the present invention may replace all or any portion or

portions of the various midsoles, insoles and bottom soles which are shown in

the figures of the present application, and may be combined with the various

other features described in reference to any of these figures in any of these

forms.

15   The removable midsole section 145 shown in Figures 11A-11P can be

integrated into, or may replace any conventional midsole, insert, or portion

thereof. If the removable midsole is used to replace a conventional mass-

market or "over the counter" shoe sole insert, for example, then any of the

features of the conventional insert can be provided by an equivalent feature,

20   including structural support or cushioning or otherwise, in the removable

midsole section 145.

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          Figs. 12A-C show a series of conventional shoe sole cross-sections in the

frontal plane at the heel utilizing both sagittal plane 181 and horizontal plane

sipes 182, and in which some or all of the sipes do not originate from any outer shoe sole surface, but rather are entirely internal. Relative motion between internal surfaces is thereby made possible to facilitate the natural deformation of the shoe sole.

5   Fig. 12A shows a group of three midsole section or lamination layers. Preferably, the central layer 188 is not glued to the other surfaces in contact with it. Instead, those surfaces are internal deformation sipes in the sagittal plane 181 and in the horizontal plane 182, which encapsulate the central layer 188, either completely or partially. The relative motion between midsole section layers at the

10   deformation sipes 181 and 182 can be enhanced with lubricating agents, either wet like silicone or dry like Teflon, of any degree of viscosity. Shoe sole materials can be closed cell if necessary to contain the lubricating agent or a non-porous surface coating or layer of lubricant can be applied. The deformation sipes can be enlarged to channels or any other practical geometric shape as sipes

15   defined in the broadest possible terms.

The relative motion can be diminished by the use of roughened surfaces or other conventional methods of increasing the coefficient of friction between midsole section layers. If even greater control of the relative motion of the central layer 188 is desired, as few as one or many more points can be glued together

20   anywhere on the internal deformation sipes 181 and 182, making them discontinuous, and the glue can be any degree of elastic or inelastic.

In Fig. 12A, the outside structure of the sagittal plane deformation sipes 181 is the shoe upper 21, which is typically flexible and relatively elastic fabric or

leather. In the absence of any connective outer material like the shoe upper shown in Fig. 12A, just the outer edges of the horizontal plane deformation sipes 182 can be glued together.

Fig. 12B shows another conventional shoe sole in frontal plane cross section at the heel with a combination similar to Fig. 12A of both horizontal and sagittal plane deformation sipes that encapsulate a central section 188. Like Fig. 12A, the Fig. 12B structure allows the relative motion of the central section 188 with its encapsulating outer midsole section 184, which encompasses its sides as well as the top surface, and bottom sole 149, both of which are attached at their common boundaries 8.

This Fig. 12B approach is analogous to the applicant's fully rounded shoe sole invention with an encapsulated midsole chamber of a pressure-transmitting medium like silicone; in this conventional shoe sole case, however, the pressure-transmitting medium is a more conventional section of a typical shoe cushioning material like PV or EVA, which also provides cushioning.

Fig. 12C is another conventional shoe sole shown in frontal plane cross section at the heel with a combination similar to Figs. 12A and 12B of both horizontal and sagittal plane deformation sipes. However, instead of encapsulating a central section 188, in Fig. 12C an upper section 187 is partially encapsulated by deformation sipes so that it acts much like the central section 188, but is more stable and more closely analogous to the actual structure of the human foot.

The upper section 187 would be analogous to the integrated mass of fatty pads, which are U-shaped and attached to the calcaneus or heel bone. Similarly, the shape of the deformation sipes is U-shaped in Fig. 12C and the upper section 187 is attached to the heel by the shoe upper, so it should function in a similar fashion to the aggregate action of the fatty pads. The major benefit of the Fig. 12C invention is that the approach is so much simpler and therefore easier and faster to implement than the highly complicated anthropomorphic design shown in Fig. 10 above. The midsole sides 185 shown in Fig. 12C are like the side portion of the encapsulating midsole 184 in Fig. 12B.

Fig. 12D shows in a frontal plane cross section at the heel a similar approach applied to the applicant's fully rounded design. Fig. 12D shows a design including an encapsulating chamber and a variation of the attachment for attaching the shoe upper to the bottom sole.

The left side of Fig. 12D shows a variation of the encapsulation of a central section 188 shown in Fig. 12B, but the encapsulation is only partial, with a center upper section of the central section 188 either attached or continuous with the encapsulating outer midsole section 184.

The right side of Fig. 12D shows a structure of deformation sipes like that of Fig. 12C, with the upper midsole section 187 provided with the capability of moving relative to both the bottom sole and the side of the midsole. The Fig. 12D structure varies from that of Fig. 12C also in that the deformation sipe 181 in roughly the sagittal plane is partial only and does not extend to the upper surface 30 of the midsole 147, as it does Fig. 12C.

Figures 13A&13B show, in frontal plane cross section at the heel area,

shoe sole structures like Figs. 5A&B, but in more detail and with the bottom sole

149 extending relatively farther up the side of the midsole.

The right side of Figs. 13A&13B show the preferred embodiment, which

5   is a relatively thin and tapering portion of the bottom sole extending up most of

the midsole and is attached to the midsole and to the shoe upper 21, which is also

attached preferably first to the upper midsole 147 where both meet at 3 and then

attached to the bottom sole where both meet at 4. The bottom sole is also

attached to the upper midsole 147 where they join at 5 and to the midsole 148 at

10   6.

The left side of Figs. 13A&13B show a more conventional attachment

arrangement, where the shoe sole is attached to a fully lasted shoe upper 21. The

bottom sole 149 is attached to: the midsole 148 where their surfaces coincide at 6,

the upper midsole 147 at 5, and the shoe upper 21 at 4.

15   Fig. 13A shows a shoe sole with another variation of an encapsulated

section 188. The encapsulated section 188 is shown bounded by the bottom sole

149 at line 8 and by the rest of the midsole 147 and 148 at line 9 . Fig. 13A

shows more detail than prior figures, including an insole (also called sock liner) 2,

which is rounded to the shape of the wearer's foot sole, just like the rest of the

20   shoe sole, so that the foot sole is supported throughout its entire range of sideways

motion, from maximum supination to maximum pronation.

The insole 2 overlaps the shoe upper 21 at 13. This approach ensures that

the load-bearing surface of the wearer's foot sole does not come in contact with

any seams which could cause abrasions. Although only the heel section is shown

in this figure, the same insole structure would preferably be used elsewhere,

particularly the forefoot. Preferably, the insole would coincide with the entire

load-bearing surface of the wearer's foot sole, including the front surface of the

5   toes, to provide support for front-to-back motion as well as sideways motion.

The Fig. 13 design provides firm flexibility by encapsulating fully or

partially, roughly the middle section of the relatively thick heel of the shoe sole

(or of other areas of the sole, such as any or all of the essential support elements

of the foot, including the base of the fifth metatarsal, the heads of the metatarsals,

10   and the first distal phalange). The outer surfaces of that encapsulated section or

sections are allowed to move relatively freely by not gluing the encapsulated

section to the surrounding shoe sole.

Firmness in the Fig. 13 design is provided by the high pressure created

under multiples of body weight loads during locomotion within the encapsulated

15   section or sections, making it relatively hard under extreme pressure, roughly like

the heel of the foot. Unlike conventional shoe soles, which are relatively

inflexible and thereby create local point pressures, particularly at the outside edge

of the shoe sole, the Fig. 13 design tends to distribute pressure evenly throughout

the encapsulated section, so the natural biomechanics of the wearer's foot sole are

20   maintained and shearing forces are more effectively dealt with.

In the Fig. 13A design, firm flexibility is provided by encapsulating

roughly the middle section of the relatively thick heel of the shoe sole or other

areas of the sole, while allowing the outer surfaces of that section to move

relatively freely by not conventionally gluing the encapsulated section to the

surrounding shoe sole. Firmness is provided by the high pressure created under

body weight loads within the encapsulated section, making it relatively hard

under extreme pressure, roughly like the heel of the foot, because it is surrounded

5   by flexible but relatively inelastic materials, particularly the bottom sole 149 (and

connecting to the shoe sole upper, which also can be constructed by flexible and

relatively inelastic material. The same U-shaped structure is thus formed on a

macro level by the shoe sole that is constructed on a micro level in the human foot

sole, as described definitively by Erich Blechschmidt in **Foot and Ankle**, March,

10   1982.

In summary, the Fig 13A design shows a shoe construction for a shoe,

comprising: a shoe sole with at least one compartment under the structural

elements of the human foot; the compartment containing a pressure-transmitting

medium composed of an independent section of midsole material that is not

15   firmly attached to the shoe sole surrounding it; pressure from normal load-bearing

is transmitted progressively at least in part to the relatively inelastic sides, top and

bottom of said shoe sole compartment, producing tension.

The Fig. 13A design can be combined with the designs shown in Figs. 58-

60 so that the compartment is surrounded by a reinforcing layer of relatively

20   flexible and inelastic fiber.

Figs. 13A&13B shows constant shoe sole thickness in frontal plane cross-

sections, but that thickness can vary somewhat (up to roughly 25% in some cases)

in frontal plane cross-sections. Fig. 13B shows a design just like Fig. 13A,

except that the encapsulated section is reduced to only the load-bearing boundary layer between the midsole 148 and the bottom sole 149. In simple terms, then, most or all of the upper surface of the bottom sole and the lower surface of the midsole are not attached, or at least not firmly attached, where they coincide at

5   line 8. The bottom sole and midsole are firmly attached only along the non-load-bearing sides of the midsole. This approach is simple and easy. The load-bearing boundary layer 8 is like the internal horizontal sipe described in Figure 12 above. The sipe can be a channel filled with flexible material or it can simply be a thinner chamber.

10   The boundary area 8 can be unglued, so that relative motion between the two surfaces is controlled only by their structural attachment together at the sides. In addition, the boundary area can be lubricated to facilitate relative motion between surfaces or lubricated by a viscous liquid that restricts motion. Or the boundary area 8 can be glued with a semi-elastic or semi-adhesive glue that

15   controls relative motion but still permits some motion. The semi-elastic or semi-adhesive glue would then serve a shock absorption function as well.

In summary, the Fig 13B design shows a shoe construction for a shoe, comprising: a shoe upper and a shoe sole that has a bottom portion with sides that are relatively flexible and inelastic; at least a portion of the bottom sole sides

20   firmly attach directly to the shoe upper; a shoe upper that is composed of material that is flexible and relatively inelastic at least where the shoe upper is attached to the bottom sole; the attached portions enveloping the other sole portions of the shoe sole; and the shoe sole having at least one horizontal boundary area serving

as a sipe that is contained internally within the shoe sole. The Fig 13B design can be combined with Figs. 58-60 to include a shoe sole bottom portion composed of material reinforced with at least one fiber layer that is relatively flexible and inelastic and that is oriented in the horizontal plane;

5   Figs. 14, 15, and 16 show frontal plane cross sectional views of a shoe sole according to the applicant's prior inventions based on the Theoretically Ideal Stability Plane, taken at about the ankle joint to show the heel section of the shoe. Figs. 17 through 26 show the same view of the applicant's enhancement of that invention. In the figures, a foot 27 is positioned in a naturally rounded shoe

10   having an upper 21 and a rounded shoe sole 28. The shoe sole normally contacts the ground 43 at about the lower central heel portion thereof., as shown in Fig. 17. The concept of the Theoretically Ideal Stability Plane defines the plane 51 in terms of a locus of points determined by the thickness(es) of the sole.

          Fig. 14 shows, in a rear cross sectional view, the inner surface of the shoe

15   sole conforming to the natural contour of the foot and the thickness of the shoe sole remaining constant in the frontal plane, so that the outer surface coincides with the theoretically ideal stability plane.

          Fig. 15 shows a fully rounded shoe sole design that follows the natural contour of all of the foot, the bottom as well as the sides, while retaining a

20   constant shoe sole thickness in the frontal plane.

          The fully rounded shoe sole assumes that the resulting slightly rounded bottom when unloaded will deform under load and flatten just as the human foot bottom is slightly rounded unloaded but flattens under load. Therefore, the shoe

sole material must be of such composition as to allow the natural deformation

following that of the foot. The design applies particularly to the heel, but to the

rest of the shoe sole as well. By providing the closest match to the natural shape

of the foot, the fully rounded design allows the foot to function as naturally as

5   possible. Under load, Fig. 15 would deform by flattening to look essentially like

Fig. 14. Seen in this light, the naturally rounded side design in Fig. 14 is a more

conventional, conservative design that is a special case of the more general fully

rounded design in Fig. 15, which is the closest to the natural form of the foot, but

the least conventional. The amount of deformation flattening used in the Fig. 14

10   design, which obviously varies under different loads, is not an essential element

of the applicant's invention.

Figs. 14 and 15 both show in frontal plane cross-sections the Theoretically

Ideal Stability Plane, which is also theoretically ideal for efficient natural motion

of all kinds, including running, jogging or walking. Fig. 15 shows the most

15   general case, the fully rounded design, which conforms to the natural shape of the

unloaded foot. For any given individual, the Theoretically Ideal Stability Plane

51 is determined, first, by the desired shoe sole thickness(es) in a frontal plane

cross section, and, second, by the natural shape of the individual's foot surface 29.

For the special case shown in Fig. 14, the Theoretically Ideal Stability

20   Plane for any particular individual (or size average of individuals) is determined,

first, by the given frontal plane cross section shoe sole thickness(es); second, by

the natural shape of the individual's foot; and, third, by the frontal plane cross-

section width of the individual's load-bearing footprint 30b, which is defined as

the upper surface of the shoe sole that is in physical contact with and supports the human foot sole.

The Theoretically Ideal Stability Plane for the special case is composed conceptually of two parts. Shown in Fig. 14, the first part is a line segment 31b of equal length and parallel to line 30b at a constant distance(s) equal to shoe sole thickness. This corresponds to a conventional shoe sole directly underneath the human foot, and also corresponds to the flattened portion of the bottom of the load-bearing shoe sole 28b. The second part is the naturally rounded stability side outer edge 31a located at each side of the first part, line segment 31b. Each point on the rounded side outer edge 31a is located at a distance which is exactly the shoe sole thickness (s) from the closest point on the rounded side inner edge 30a.

In summary, the Theoretically Ideal Stability Plane is used to determine a geometrically precise bottom contour of the shoe sole based on a top contour that conforms to the contour of the foot.

It can be stated unequivocally that any shoe sole contour, even of similar contour, that exceeds the Theoretically Ideal Stability Plane will restrict natural foot motion, while any less than that plane will degrade natural stability, in direct proportion to the amount of the deviation. The theoretical ideal was taken to be that which is closest to natural.

Fig. 16 illustrates in frontal plane cross-section another variation of a shoe sole that uses stabilizing quadrants 26 at the outer edge of a conventional shoe sole 28b illustrated generally at the reference numeral 28. The stabilizing quadrants would be abbreviated in actual embodiments.

Fig. 17 illustrates the shoe sole side thickness increasing beyond the

Theoretically Ideal Stability Plane to increase stability somewhat beyond its

natural level. The unavoidable trade-off which results is that natural motion

would be restricted somewhat and the weight of the shoe sole would increase

5   somewhat.

Fig. 17 shows a situation wherein the thickness of the sole at each of the

opposed sides is thicker at the portions of the sole 31a by a thickness which

gradually varies continuously from a thickness (s) through a thickness (s+s1), to a

thickness (s+s2). These designs recognize that lifetime use of existing shoes, the

10   design of which has an inherent flaw that continually disrupts natural human

biomechanics, has produced thereby actual structural changes in a human foot and

ankle to an extent that must be compensated for. Specifically, one of the most

common of the abnormal effects of the inherent existing flaw is a weakening of

the long arch of the foot, increasing pronation. These designs therefore provide

15   greater than natural stability and should be particularly useful to individuals,

generally with low arches, prone to pronate excessively, and could be used only

on the medial side. Similarly, individuals with high arches and a tendency to over

supinate and who are vulnerable to lateral ankle sprains would also benefit, and

the design could be used only on the lateral side. A shoe for the general

20   population that compensates for both weaknesses in the same shoe would

incorporate the enhanced stability of the design compensation on both sides.

Fig. 17, like Figs. 14 and 15, shows an embodiment which allows the shoe

sole to deform naturally, closely paralleling the natural deformation of the bare

foot under load. In addition, shoe sole material must be of such composition as to allow natural deformation similar to that of the foot.

This design retains the concept of contouring the shape of the shoe sole to the shape of the human foot. The difference is that the shoe sole thickness in the

5   frontal plane is allowed to vary rather than remain uniformly constant. More specifically, Figs. 17, 18, 19, 20, and 24 show, in frontal plane cross sections at the heel, that the shoe sole thickness can increase beyond the theoretically ideal stability plane 51, in order to provide greater than natural stability. Such variations (and the following variations) can be consistent through all frontal

10 plane cross sections, so that there are proportionately equal increases to the theoretically ideal stability plane 51 from the front of the shoe sole to the back. Alternatively, the thickness can vary, preferably continuously, from one frontal plane to the next.

The exact amount of the increase in shoe sole thickness beyond the

15 theoretically ideal stability plane is to be determined empirically. Ideally, right and left shoe soles would be custom designed for each individual based on a biomechanical analysis of the extent of his or her foot and ankle dysfunction in order to provide for optimal support. It is expected that any such custom designed shoes would generally have a thickness exceeding the Theoretically

20 Ideal Stability Plane by an amount up to 5 or 10 percent. However, the thickness could exceed the Theoretically Ideal Stability Plane by an amount up to 25 percent. The optimal contour for the increased thickness may also be determined empirically.

Fig. 18 shows a variation of the enhanced fully rounded design wherein the shoe sole begins to thicken beyond the theoretically ideal stability plane 51 somewhat offset to the sides.

Fig. 19 shows a thickness variation which is symmetrical as in the case of Fig. 17 and 18, but wherein the shoe sole begins to thicken beyond the Theoretically Ideal Stability Plane 51 directly underneath the foot heel 27 on about a center line of the shoe sole. In fact, in this case the thickness of the shoe sole is the same as the Theoretically Ideal Stability Plane only at that beginning point underneath the upright foot. For the embodiment wherein the shoe sole thickness varies, the Theoretically Ideal Stability Plane is determined by the least thickness in the shoe sole's direct load-bearing portion meaning that portion with direct tread contact on the ground. The outer edge or periphery of the shoe sole is obviously excluded, since the thickness there always decreases to zero. Note that the capability of the design to deform naturally may make some portions of the shoe sole load-bearing when they are actually under a load, especially walking or running, even though they may not be when the shoe sole is not under a load.

Fig. 20 shows that the thickness can also increase and then decrease. Other thickness variation sequences are also possible. The variation in side contour thickness can be either symmetrical on both sides or asymmetrical, particularly with the medial side providing more stability than the lateral side, although many other asymmetrical variations are possible. Also, the pattern of the right foot can vary from that of the left foot.

Figs. 21, 22, 23 and 25 show that similar variations in shoe midsole (other

portions of the shoe sole area not shown) density can provide similar, but

reduced, effects to the variations in shoe sole thickness described previously in

Figs. 17-20. The major advantage of this approach is that the structural Theore-

5   tically Ideal Stability Plane is retained, so that naturally optimal stability and

efficient motion are retained to the maximum extent possible.

The forms of dual and tri-density midsoles shown in the figures are

extremely common in the current art of athletic shoes, and any number of

densities are theoretically possible, although an angled alternation of just two

10   densities like that shown in Fig. 21 provides continually changing composite

density. However, multi-densities in the midsole were not preferred since only a

uniform density provides a neutral shoe sole design that does not interfere with

natural foot and ankle biomechanics in the way that multi-density shoe soles do,

which is by providing different amounts of support to different parts of the foot.

15   In these figures, the density of the sole material designated by the legend (d^1) is

firmer than (d) while (d^2) is the firmest of the three representative densities

shown. In Fig. 21, a dual density sole is shown, with (d) having the less firm

density.

It should be noted that shoe soles using a combination both of sole

20   thicknesses greater than the Theoretically Ideal Stability Plane and of midsole

density variations like those just described are also possible but not shown.

Fig. 26 shows a bottom sole tread design that provides about the same

overall shoe sole density variation as that provided in Fig. 23 by midsole density

variation. The less supporting tread there is under any particular portion of the shoe sole, the less effective overall shoe sole density there is, since the midsole above that portion will deform more easily than if it were fully supported.

Fig. 27 shows embodiments like those in Figs. 17 through 26 but wherein a portion of the shoe sole thickness is decreased to less than the theoretically ideal stability plane. It is anticipated that some individuals with foot and ankle biomechanics that have been degraded by existing shoes may benefit from such embodiments, which would provide less than natural stability but greater freedom of motion, and less shoe sole weight and bulk. In particular, it is anticipated that individuals with overly rigid feet, those with restricted range of motion, and those tending to over-supinate may benefit from the Fig. 14 embodiments. Even more particularly, it is expected that the invention will benefit individuals with significant bilateral foot function asymmetry: namely, a tendency toward pronation on one foot and supination on the other foot. Consequently, it is antici-pated that this embodiment would be used only on the shoe sole of the supinating foot, and on the inside portion only, possibly only a portion thereof. It is expected that the range less than the Theoretically Ideal Stability Plane would be a maximum of about five to ten percent, though a maximum of up to twenty-five percent may be beneficial to some individuals.

Fig. 27A shows an embodiment like Figs. 17 and 20, but with naturally rounded sides less than the Theoretically Ideal Stability Plane. Fig. 27B shows an embodiment like the fully rounded design in Figs. 18 and 19, but with a shoe sole thickness decreasing with increasing distance from the center portion of the sole.

Fig. 27C shows an embodiment like the quadrant-sided design of Fig. 24, but with the quadrant sides increasingly reduced from the Theoretically Ideal Stability Plane.

The lesser-sided design of Fig. 27 would also apply to the Figs. 21-3 and

5   25 density variation approach and to the Fig. 26 approach using tread design to approximate density variation.

Fig. 28A-28C show, in cross-sections that with the quadrant-sided design of Figs. 16, 24, 25 and 27C that it is possible to have shoe sole sides that are both greater and lesser than the theoretically ideal stability plane in the same shoe. The

10   radius of an intermediate shoe sole thickness, taken at (s^2) at the base of the fifth metatarsal in Fig. 28B, is maintained constant throughout the quadrant sides of the shoe sole, including both the heel, Fig. 28C, and the forefoot, Fig. 28A, so that the side thickness is less than the Theoretically Ideal Stability Plane at the heel and more at the forefoot. Though possible, this is not a preferred approach.

15   The same approach can be applied to the naturally rounded sides or fully rounded designs described in Figs. 14, 15, 17-23 and 26, but it is also not preferred. In addition, as shown in Figs. 28D-28F, it is possible to have shoe sole sides that are both greater and lesser than the Theoretically Ideal Stability Plane in the same shoe, like Figs. 28A-28C, but wherein the side thickness (or radius) is

20   neither constant like Figs 28A-28C or varying directly with shoe sole thickness, but instead varying quite indirectly with shoe sole thickness. As shown in Figs 28D-28F, the shoe sole side thickness varies from somewhat less than the shoe sole thickness at the heel to somewhat more at the forefoot. This approach,

though possible, is again not preferred, and can be applied to the quadrant sided

design, but is not preferred there either.

Fig. 29 shows in a frontal plane cross-section at the heel (center of ankle

joint) the general concept of a shoe sole 28 that conforms to the natural shape of

5   the human foot 27 and that has a constant thickness (s) in frontal plane cross

sections. The surface 29 of the bottom and sides of the foot 27 should correspond

exactly to the upper surface 30 of the rounded shoe sole 28. The shoe sole

thickness is defined as the shortest distance (s) between any point on the upper

surface 30 of the rounded shoe sole 28 and the lower surface 31. In effect, the

10   applicant's general concept is a rounded shoe sole 28 that wraps around and

conforms to the natural contours of the foot 27 as if the rounded shoe sole 28

were made of a theoretical single flat sheet of shoe sole material of uniform

thickness, wrapped around the foot with no distortion or deformation of that sheet

as it is bent to the foot's contours. To overcome real world deformation problems

15   associated with such bending or wrapping around contours, actual construction of

the shoe sole contours of uniform thickness will preferably involve the use of

multiple sheet lamination or injection molding techniques.

Figs. 30A, 30B, and 30C illustrate in frontal plane cross-section use of

naturally rounded stabilizing sides 28a at the outer edge of a shoe sole 28b

20   illustrated generally at the reference numeral 28. This eliminates the unnatural

sharp bottom edge, especially of flared shoes, in favor of a naturally rounded shoe

sole outside 31 as shown in Fig. 29. The side or inner edge 30a of the shoe sole

stability side 28a is rounded like the natural form on the side or edge of the

human foot, as is the outside or outer edge 31a of the shoe sole stability side 28a

to follow a theoretically ideal stability plane. The thickness (s) of the rounded

shoe sole 28 is maintained exactly constant, even if the shoe sole is tilted to either

side, or forward or backward. Thus, the naturally rounded stabilizing sides 28a,

5   are defined as the same as the thickness 33 of the shoe sole 28 so that, in cross-

section, the shoe sole comprises a stable rounded shoe sole 28 having at its outer

edge naturally rounded stabilizing sides 28a with a surface 31a representing a

portion of a Theoretically Ideal Stability Plane and described by naturally rounded

sides equal to the thickness (s) of the rounded shoe sole 28. The top of the shoe

10   sole 30b coincides with the shoe wearer's load-bearing footprint, since in the case

shown the shape of the foot is assumed to be load-bearing and therefore flat along

the bottom. A top edge 32 of the naturally rounded stability side 28a can be

located at any point along the rounded side of the outer surface of the foot 29,

while the inner edge 33 of the naturally rounded side 28a coincides with the

15   perpendicular sides 34 of the load-bearing shoe sole 28b. In practice, the rounded

shoe sole 28 is preferably integrally formed from the portions 28b and 28a. Thus,

the Theoretically Ideal Stability Plane includes the contours 31a merging into the

lower surface 31b of the rounded shoe sole 28.

Preferably, the peripheral extent 36 of the load-bearing portion of the sole

20   28b of the shoe includes all of the support structures of the foot but extends no

further than the outer edge of the foot sole 37 as defined by a load-bearing

footprint, as shown in Fig. 30D, which is a top view of the upper shoe sole

surface 30b. Fig. 30D thus illustrates a foot outline at numeral 37 and a

recommended sole outline 36 relative thereto. Thus, a horizontal plane outline of the top of the load-bearing portion of the shoe sole, therefore exclusive of rounded stability sides, should, preferably, coincide as nearly as practicable with the load-bearing portion of the foot sole with which it comes into contact. Such a

5 horizontal outline, as best seen in Figs. 30D and 33D, should remain uniform throughout the entire thickness of the shoe sole eliminating negative or positive sole flare so that the sides are exactly perpendicular to the horizontal plane as shown in Fig. 30B. Preferably, the density of the shoe sole material is uniform.

As shown diagrammatically in Fig. 31, preferably, as the heel lift or

10 wedge 38 of thickness (s1) increases the total thickness (s + s1) of the combined midsole and outersole 39 of thickness (s) in an aft direction of the shoe, the naturally rounded sides 28a increase in thickness exactly the same amount according to the principles discussed in connection with Fig. 30. Thus, the thickness of the inner edge 33 of the naturally rounded side is always equal to the

15 constant thickness (s) of the load-bearing shoe sole 28b in the frontal cross-sectional plane.

As shown in Fig. 31B, for a shoe that follows a more conventional horizontal plane outline, the sole can be improved significantly by the addition of a naturally rounded side 28a which correspondingly varies with the thickness of

20 the shoe sole and changes in the frontal plane according to the shoe heel lift 38. Thus, as illustrated in Fig. 31B, the thickness of the naturally rounded side 28a in the heel section is equal to the thickness (s + s1) of the rounded shoe sole 28 which is thicker than the shoe sole 39 thickness (s) shown in Fig. 31A by an

amount equivalent to the heel lift 38 thickness (s1). In the generalized case, the thickness (s) of the rounded side is thus always equal to the thickness (s) of the shoe sole.

Fig. 32 illustrates a side cross-sectional view of a shoe to which the invention has been applied and is also shown in a top plane view in Fig. 33.

Thus, Figs. 33A, 33B, and 33C represent frontal plane cross-sections taken along the forefoot, at the base of the fifth metatarsal, and at the heel, thus illustrating that the shoe sole thickness is constant at each frontal plane cross-section, even though that thickness varies from front to back, due to the heel lift 38 as shown in Fig. 32, and that the thickness of the naturally rounded sides is equal to the shoe sole thickness in each Fig. 33A-33C cross section. Moreover, in Fig. 33D, a horizontal plane overview of the left foot, it can be seen that the contour of the sole follows the preferred principle in matching, as nearly as practical, the load-bearing sole print shown in Fig. 30D.

Fig. 34 illustrates an embodiment of the invention which utilizes varying portions of the Theoretically Ideal Stability Plane 51 in the naturally rounded sides 28a in order to reduce the weight and bulk of the sole, while accepting a sacrifice in some stability of the shoe. Thus, Fig. 34A illustrates the preferred embodiment as described above in connection with Fig. 31 wherein the outer edge 31a of the naturally rounded sides 28a follows a Theoretically Ideal Stability Plane 51. As in Figs. 29 and 30, the rounded surfaces 31a, and the lower surface of the sole 31b lie along the Theoretically Ideal Stability Plane 51. As shown in Fig. 34B, an engineering trade-off results in an abbreviation within the

Theoretically Ideal Stability Plane 51 by forming a naturally rounded side surface 53a approximating the natural contour of the foot (or more geometrically regular, which is less preferred) at an angle relative to the upper plane of the rounded shoe sole 28 so that only a smaller portion of the rounded side 28a defined by the

5   constant thickness lying along the surface 31a is coplanar with the Theoretically Ideal Stability Plane 51. Figs. 34C and 34C show similar embodiments wherein each engineering trade-off shown results in progressively smaller portions of rounded side 28a, which lies along the Theoretically Ideal Stability Plane 51. The portion of the surface 31a merges into the upper side surface 53a of the naturally

10   rounded side 28a.

The embodiment of Fig. 34 may be desirable for portions of the shoe sole which are less frequently used so that the additional part of the side is used less frequently. For example, a shoe may typically roll out laterally, in an inversion mode, to about 20° on the order of 100 times for each single time it rolls out to

15   40°. For a basketball shoe, shown in Fig. 34B, the extra stability is needed. Yet, the added shoe weight to cover that infrequently experienced range of motion is about equivalent to covering the frequently encounter range. Since, in a racing shoe this weight might not be desirable, an engineering trade-off of the type shown in Fig. 34D is possible. A typical athletic/jogging shoe is shown in Fig.

20   34C. The range of possible variations is limitless.

Fig. 35 shows the Theoretically Ideal Stability Plane 51 in defining embodiments of the shoe sole having differing tread or cleat patterns. Thus, Fig. 35 illustrates that the invention is applicable to shoe soles having conventional

bottom treads. Accordingly, Fig. 35A is similar to Fig. 34B further including a tread portion 60, while Fig. 35B is also similar to Fig. 34B wherein the sole includes a cleated portion 61. The surface 63 to which the cleat bases are affixed should preferably be on the same plane and parallel the theoretically ideal stability

5   plane 51, since in soft ground that surface rather than the cleats become load-bearing. The embodiment in Fig. 35C is similar to Fig. 34C showing still an alternative tread construction 62. In each case, the load-bearing outer surface of the tread or cleat pattern 60-62 lies along the Theoretically Ideal Stability Plane 51.

10   Fig. 36 illustrates in a curve 70 the range of side to side inversion/eversion motion of the ankle center of gravity 71 from the shoe shown in frontal plane cross-section at the ankle. Thus, in a static case where the center of gravity 71 lies at approximately the mid-point of the sole, and assuming that the shoe inverts or everts from 0° to 20° to 40°, as shown in progressions 36A, 36B and 36C, the

15   locus of points of motion for the center of gravity thus defines the curve 70 wherein the center of gravity 71 maintains a steady level motion with no vertical component through 40° of inversion or eversion. For the embodiment shown, the shoe sole stability equilibrium point is at 28° (at point 74) and in no case is there a pivoting edge to define a rotation point. The inherently superior side to side

20   stability of the design provides pronation control (or eversion), as well as lateral (or inversion) control. In marked contrast to conventional shoe sole designs, this shoe design creates virtually no abnormal torque to resist natural inversion/eversion motion or to destabilize the ankle joint.

Fig. 37 thus compares the range of motion of the center of gravity for the invention, as shown in curve 70, in comparison to curve 80 for the conventional wide heel flare and a curve 82 for a narrow rectangle the width of a human heel. Since the shoe stability limit is 28° in the inverted mode, the shoe sole is stable at

5   the 20° approximate bare foot inversion limit. That factor, and the broad base of support rather than the sharp bottom edge of the prior art, make the contour design stable even in the most extreme case as shown in Figs. 36A-36C and permit the inherent stability of the bare foot to dominate without interference, unlike existing designs, by providing constant, unvarying shoe sole thickness in

10   frontal plane cross sections. The stability superiority of the rounded side design is thus clear when observing how much flatter its center of gravity curve 70 is than in existing popular wide flare design 80. The curve demonstrates that the rounded side design has significantly more efficient natural 7° inversion/eversion motion than the narrow rectangle design the width of a human heel, and very

15   much more efficient than the conventional wide flare design. At the same time, the rounded side design is more stable *in extremis* than either conventional design because of the absence of destabilizing torque.

Figs. 38A-38D illustrate, in frontal plane cross sections, the naturally rounded sides design extended to the other natural contours underneath the load-

20   bearing foot, such as the main longitudinal arch, the metatarsal (or forefoot) arch, and the ridge between the heads of the metatarsals (forefoot) and the heads of the distal phalanges (toes). As shown, the shoe sole thickness remains constant as the contour of the shoe sole follows that of the sides and bottom of the load-bearing

foot. Fig. 38E shows a sagittal plane cross section of the shoe sole conforming to the contour of the bottom of the load-bearing foot, with thickness varying according to the heel lift 38. Fig. 38F shows a horizontal plane top view of the left foot that shows the areas 85 of the shoe sole that correspond to the flattened

5 portions of the foot sole that are in contact with the ground when load-bearing. Contour lines 86 and 87 show approximately the relative height of the shoe sole contours above the flattened load-bearing areas 85 but within roughly the peripheral extent 35 of the upper surface of sole 30 shown in Fig. 30. A horizontal plane bottom view (not shown) of Fig. 38F would be the exact recipro-

10 cal or converse of Fig. 38F (i.e. peaks and valleys contours would be exactly reversed).

Figs. 39A-39D show, in frontal plane cross sections, the fully rounded shoe sole design extended to the bottom of the entire non-load-bearing foot. Fig. 39E shows a sagittal plane cross section. The shoe sole contours underneath the

15 foot are the same as Figs. 38A-38E except that there are no flattened areas corresponding to the flattened areas of the load-bearing foot. The exclusively rounded contours of the shoe sole follow those of the unloaded foot. A heel lift 38 and a midsole and outersole 39, the same as that of Fig. 38, is incorporated in this embodiment, but is not shown in Fig. 39.

20 Fig. 40 shows the horizontal plane top view of the left foot corresponding to the fully rounded design described in Figs. 39A-39E, but abbreviated along the sides to only essential structural support and propulsion elements. Shoe sole material density can be increased in the unabbreviated essential elements to

compensate for increased pressure loading there. The essential structural support

elements are the base and lateral tuberosity of the calcaneus 95, the heads of the

metatarsals 96, and the base of the fifth metatarsal 97. They must be supported

both underneath and to the outside for stability. The essential propulsion element

5   is the head of first distal phalange 98. The medial (inside) and lateral (outside)

sides supporting the base of the calcaneus are shown in Fig. 40 oriented roughly

along either side of the horizontal plane subtalar ankle joint axis, but can be

located also more conventionally along the longitudinal axis of the shoe sole.

Fig. 40 shows that the naturally rounded stability sides need not be used except in

10   the identified essential areas. Weight savings and flexibility improvements can be

made by omitting the non-essential stability sides. Contour lines 85 through 89

show approximately the relative height of the shoe sole contours within roughly

the peripheral extent 35 of the undeformed upper surface of shoe sole 30 shown

in Fig. 17. A horizontal plane bottom view (not shown) of Fig. 40 would be the

15   exact reciprocal or converse of Fig. 40 (i.e. peaks and valleys contours would be

exactly reversed).

Fig. 41A shows a development of street shoes with naturally rounded sole

sides incorporating features according to the present invention. Fig. 41A

develops a Theoretically Ideal Stability Plane 51, as described above, for such a

20   street shoe, wherein the thickness of the naturally rounded sides equals the shoe

sole thickness. The resulting street shoe with a correctly rounded sole is thus

shown in frontal plane heel cross section in Fig. 41A, with side edges

perpendicular to the ground, as is typical. Fig. 41B shows a similar street shoe

with a fully rounded design, including the bottom of the sole. Accordingly, the invention can be applied to an unconventional heel lift shoe, like a simple wedge, or to the most conventional design of a typical walking shoe with its heel separated from the forefoot by a hollow under the instep. The invention can be applied just at the shoe heel or to the entire shoe sole. With the invention, as so applied, the stability and natural motion of any existing shoe design, except high heels or spike heels, can be significantly improved by the naturally rounded shoe sole design.

Fig. 42 shows a non-optimal but interim or low cost approach to shoe sole construction, whereby the midsole 148 and heel lift 38 are produced conventionally, or nearly so (at least leaving the midsole bottom surface flat, though the sides can be rounded), while the bottom or outer sole 149 includes most or all of the special contours of the design. Not only would that completely or mostly limit the special contours to the bottom sole, which would be molded specially; it would also ease assembly, since two flat surfaces of the bottom of the midsole and the top of the bottom sole could be mated together with less difficulty than two rounded surfaces, as would be the case otherwise.

The advantage of this approach is seen in the naturally rounded design example illustrated in Fig. 42A, which shows some contours on the relatively softer midsole sides, which are subject to less wear but benefit from greater traction for stability and ease of deformation, while the relatively harder rounded bottom sole provides good wear for the load-bearing areas.

Fig. 42B shows in a quadrant side design the concept applied to conventional street shoe heels, which are usually separated from the forefoot by a hollow instep area under the main longitudinal arch.

Fig. 42C shows in frontal plane cross-section the concept applied to the quadrant sided or single plane design and indicating in Fig. 42D in the shaded area 129 of the bottom sole that portion which should be honeycombed (axis on the horizontal plane) to reduce the density of the relatively hard outer sole to that of the midsole material to provide for relatively uniform shoe density.

Generally, insoles or sock liners should be considered structurally and functionally as part of the shoe sole, as should any shoe material between foot and ground, like the bottom of the shoe upper in a slip-lasted shoe or the board in a board-lasted shoe.

Fig. 43 shows in a real illustration a foot 27 in position for a new biomechanical test that is the basis for the discovery that ankle sprains are in fact unnatural for the bare foot. The test simulates a lateral ankle sprain, where the foot 27 - on the ground 43 - rolls or tilts to the outside, to the extreme end of its normal range of motion, which is usually about 20 degrees at the outer surface of the foot 29, as shown in a rear view of a bare (right) heel in Fig. 43. Lateral (inversion) sprains are the most common ankle sprains, accounting for about three-fourths of all ankle sprains.

The especially novel aspect of the testing approach is to perform the ankle spraining simulation while standing stationary. The absence of forward motion is the key to the dramatic success of the test because otherwise it is impossible to

recreate for testing purposes the actual foot and ankle motion that occurs during a

lateral ankle sprain, and simultaneously to do it in a controlled manner, while at

normal running speed or even jogging slowly, or walking. Without the critical

control achieved by slowing forward motion all the way down to zero, any test

5   subject would end up with a sprained ankle.

That is because actual running in the real world is dynamic and involves a

repetitive force maximum of three times one's full body weight for each footstep,

with sudden peaks up to roughly five or six times for quick stops, missteps, and

direction changes, as might be experienced when spraining an ankle. In contrast,

10   in the static simulation test, the forces are tightly controlled and moderate, ranging

from no force at all up to whatever maximum amount that is comfortable.

The Stationary Sprain Simulation Test (SSST) consists simply of standing

stationary with one foot bare and the other shod with any shoe. Each foot

alternately is carefully tilted to the outside up to the extreme end of its range of

15   motion, simulating a lateral ankle sprain.

The SSST clearly identifies what can be no less than a fundamental flaw

in existing shoe design. It demonstrates conclusively that nature's biomechanical

system, the bare foot, is far superior in stability to man's artificial shoe design.

Unfortunately, it also demonstrates that the shoe's severe instability overpowers

20   the natural stability of the human foot and synthetically creates a combined

biomechanical system that is artificially unstable. The shoe is the weak link.

The test shows that the bare foot is inherently stable at the approximate 20

degree end of normal joint range because of the wide, steady foundation the bare

heel 29 provides the ankle joint, as seen in Fig. 43. In fact, the area of physical contact of the bare heel 29 with the ground 43 is not much less when tilted all the way out to 20 degrees as when upright at 0 degrees.

The SSST provides a natural yardstick, totally missing until now, to

5   determine whether any given shoe allows the foot within it to function naturally. If a shoe cannot pass this simple test, it is positive proof that a particular shoe is interfering with natural foot and ankle biomechanics. The only question is the exact extent of the interference beyond that demonstrated by the SSST.

Conversely, the applicant's designs employ shoe soles thick enough to

10 provide cushioning (thin-soled and heel-less moccasins do pass the test, but do not provide cushioning and only moderate protection) and naturally stable performance, like the bare foot, in the SSST.

Fig. 44 shows that, in complete contrast the foot equipped with a conventional athletic shoe, designated generally by the reference numeral 20 and

15 having an upper 21, though initially very stable while resting completely flat on the ground, becomes immediately unstable when the shoe sole 22 is tilted to the outside. The tilting motion lifts from contact with the ground all of the shoe sole 22 except the artificially sharp edge of the bottom outside corner. The shoe sole instability increases the farther the foot is rolled laterally. Eventually, the

20 instability induced by the shoe itself is so great that the normal load-bearing pressure of full body weight would actively force an ankle sprain, if not controlled. The abnormal tilting motion of the shoe does not stop at the bare foot's natural 20 degree limit, as can be seen from the 45 degree tilt of the shoe

heel in Fig. 44.

That continued outward rotation of the shoe past 20 degrees causes the foot to slip within the shoe, shifting its position within the shoe to the outside edge, further increasing the shoe's structural instability. The slipping of the foot within the shoe is caused by the natural tendency of the foot to slide down the typically flat surface of the tilted shoe sole; the more the tilt, the stronger the tendency. The heel is shown in Fig. 44 because of its primary importance in sprains due to its direct physical connection to the ankle ligaments that are torn in an ankle sprain and also because of the heel's predominant role within the foot in bearing body weight.

It is easy to see in the two figures, Figures 43 and 44, how totally different the physical shape of the natural bare foot is compared to the shape of the artificial, conventional shoe sole. It is strikingly odd that the two objects, which apparently both have the same biomechanical function, have completely different physical shapes. Moreover, the shoe sole clearly does not deform the same way the human foot sole does, primarily as a consequence of its dissimilar shape.

Figs. 45A-45C illustrate clearly the principle of natural deformation as it applies to the applicant's designs, even though design diagrams like those preceding are normally shown in an ideal state, without any functional deformation, obviously to show their exact shape for proper construction. That natural structural shape, with its contour paralleling the foot, enables the shoe sole to deform naturally like the foot. The natural deformation feature creates such an important functional advantage it will be illustrated and discussed here fully.

Note in the figures that even when the shoe sole shape is deformed, the constant shoe sole thickness in the frontal plane feature of the invention is maintained.

Fig. 45A shows upright, unloaded and therefore undeformed the fully rounded shoe sole design indicated in Fig. 15 above. Fig. 45A shows a fully

5   rounded shoe sole design that follows the natural contour of all of the foot sole, the bottom as well as the sides. The fully rounded shoe sole assumes that the resulting slightly rounded bottom when unloaded will deform under load as shown in Fig. 45B and flatten just as the human foot bottom is slightly rounded unloaded but flattens under load, like Figure 14 above. Therefore, the shoe sole

10 material must be of such composition as to allow the natural deformation following that of the foot. The design applies particularly to the heel, but to the rest of the shoe sole as well. By providing the closest possible match to the natural shape of the foot, the fully rounded design allows the foot to function as naturally as possible. Under load, Fig. 45A would deform by flattening to look

15 essentially like Fig. 45B.

Figs. 45A and 45B show in frontal plane cross-section the Theoretically Ideal Stability Plane which is also theoretically ideal for efficient natural motion of all kinds, including running, jogging or walking. For any given individual, the Theoretically Ideal Stability Plane 51 is determined, first, by the desired shoe sole

20 thickness (s) in a frontal plane cross section, and, second, by the natural shape of the individual's foot surface 29.

For the case shown in Fig. 45B, the Theoretically Ideal Stability Plane for any particular individual (or size average of individuals) is determined, first, by

the given frontal plane cross-section shoe sole thickness (s); second, by the natural shape of the individual's foot;. and, third, by the frontal plane cross section width of the individual's load-bearing footprint which is defined as the upper surface of the shoe sole that is in physical contact with and supports the human

5   foot sole.

Fig. 45B shows the same fully rounded design when upright, under normal load (body weight) and therefore deformed naturally in a manner very closely paralleling the natural deformation under the same load of the foot. An almost identical portion of the foot sole that is flattened in deformation is also

10   flattened in deformation in the shoe sole. Fig. 45C shows the same design when tilted outward 20 degrees laterally, the normal bare foot limit; with virtually equal accuracy it shows the opposite foot tilted 20 degrees inward, in fairly severe pronation. As shown, the deformation of the rounded shoe sole 28 again very closely parallels that of the foot, even as it tilts. Just as the area of foot contact is

15   almost as great when tilted 20 degrees, the flattened area of the deformed shoe sole is also nearly the same as when upright. Consequently, the bare foot fully supported structurally and its natural stability is maintained undiminished, regardless of shoe tilt. In marked contrast, a conventional shoe, shown in Fig. 2, makes contact with the ground with only its relatively sharp edge when tilted and

20   is therefore inherently unstable.

The capability to deform naturally is a design feature of the applicant's naturally rounded shoe sole designs, whether fully rounded or rounded only at the sides, though the fully rounded design is most optimal and is the most natural,

general case, assuming shoe sole material such as to allow natural deformation. It is an important feature because, by following the natural deformation of the human foot, the naturally deforming shoe sole can avoid interfering with the natural biomechanics of the foot and ankle.

5   Fig. 45C also represents with reasonable accuracy a shoe sole design corresponding to Fig. 45B, a naturally rounded shoe sole with a conventional built-in flattening deformation, as in Fig. 14 above, except that design would have a slight crimp at 146. Seen in this light, the naturally rounded side design in Fig. 45B is a more conventional, conservative design that is a special case of the more
10   generally fully rounded design in Fig. 45A, which is the closest to the natural form of the foot, but the least conventional. The natural deformation of the applicant's shoe sole design follows that of the foot very closely so that both provide a nearly equal flattened base to stabilize the foot.

       Fig. 46 shows the preferred relative density of the shoe sole, including the
15   insole as a part, in order to maximize the shoe sole's ability to deform naturally following the natural deformation of the foot sole. Regardless of how many shoe sole layers (including insole) or laminations of differing material densities and flexibility are used in total, the softest and most flexible material 147 should be closest to the foot sole, with a progression through less soft 148, such as a
20   midsole or heel lift, to the firmest and least flexible 149 at the outermost shoe sole layer, the bottom sole. This arrangement helps to avoid the unnatural side lever arm/torque problem mentioned in the previous several figures. That problem is most severe when the shoe sole is relatively hard and non-deforming uniformly

throughout the shoe sole, like most conventional street shoes, since hard material transmits the destabilizing torque most effectively by providing a rigid lever arm.

The relative density shown in Fig. 46 also helps to allow the shoe sole to duplicate the same kind of natural deformation exhibited by the bare foot sole in

5   Fig. 43, since the shoe sole layers closest to the foot, and therefore with the most severe contours, have to deform the most in order to flatten like the barefoot and consequently need to be soft to do so easily. This shoe sole arrangement also replicates roughly the natural bare foot, which is covered with a very tough "Seri boot" outer surface (protecting a softer cushioning interior of fat pads) among

10   primitive barefoot populations.

Finally, the use of natural relative density as indicated in this figure will allow more anthropomorphic embodiments of the applicant's designs (right and left sides of Fig. 46 show variations of different degrees) with sides going higher around the side contour of the foot and thereby blending more naturally with the

15   sides of the foot. These conforming sides will not be effective as destabilizing lever arms because the shoe sole material there would be soft and unresponsive in transmitting torque, since the lever arm will bend.

As a point of clarification, the forgoing principle of preferred relative density refers to proximity to the foot and is not inconsistent with the term

20   "uniform density" used in conjunction with certain embodiments of applicant's invention. Uniform shoe sole density is preferred strictly in the sense of preserving even and natural support to the foot like the ground provides, so that a neutral starting point can be established, against which so-called improvements

can be measured. The preferred uniform density is in marked contrast to the

common practice in athletic shoes today, especially those beyond cheap or "bare

bones" models, of increasing or decreasing the density of the shoe sole,

particularly in the midsole, in various areas underneath the foot to provide extra

5   support or special softness where "believed necessary. The same effect is also

created by areas either supported or unsupported by the tread pattern of the

bottom sole. The most common example of this practice is the use of denser

midsole material under the inside portion of the heel, to counteract excessive

pronation.

10   Fig. 47 illustrates that the applicant's naturally rounded shoe sole sides can

be made to provide a fit so close as to approximate a custom fit. By molding each

mass-produced shoe size with sides that are bent in somewhat from the position

29 they would normally be in to conform to that standard size shoe last, the shoe

soles so produced will very gently hold the sides of each individual foot exactly.

15   Since the shoe sole is designed as described in connection with Fig. 46 to deform

easily and naturally like that of the bare foot, it will deform easily to provide this

designed-in custom fit. The greater the flexibility of the shoe sole sides, the

greater the range of individual foot size variations can be custom fit by a standard

size. This approach applies to the fully rounded design described here in Fig.

20   45A and in Fig. 15 above, which would be even more effective than the naturally

rounded sides design shown in Fig. 47.

Besides providing a better fit, the intentional undersizing of the flexible

shoe sole sides of Figure 47 allows for a simplified design utilizing a geometric

approximation of the true actual contour of the human. This geometric

approximation is close enough to provide a virtual custom fit, when compensated

for by the flexible undersizing from standard shoe lasts described above.

Fig. 48 illustrates a fully rounded design, but abbreviated along the sides

to only essential structural stability and propulsion shoe sole elements as shown in

Fig. 11 G-L above combined with freely articulating structural elements under-

neath the foot. The unifying concept is that, on both the sides and underneath the

main load bearing portions of the shoe sole, only the important structural (i.e.

bone) elements of the foot should be supported by the shoe sole, if the natural

flexibility of the foot is to be paralleled accurately in shoe sole flexibility, so that

the shoe sole does not interfere with the foot's natural motion. In a sense, the shoe

sole should be composed of the same main structural elements as the foot and

they should articulate with each other just as do the main joints of the foot.

Fig. 48E shows the horizontal plane bottom view of the right foot

corresponding to the fully rounded design previously described, but abbreviated

along the sides to only essential structural support and propulsion elements. Shoe

sole material density can be increased in the unabbreviated essential elements to

compensate for increased pressure loading there. The essential structural support

elements are the base and lateral tuberosity of the calcaneus 95, the heads of the

metatarsals 96, and the base of the fifth metatarsal 97 (and the adjoining cuboid in

some individuals). They must be supported both underneath and to the outside

edge of the foot for stability. The essential propulsion element is the head of the

first distal phalange 98. Fig. 48 shows that the naturally rounded stability sides

need not be used except in the identified essential areas. Weight savings and flexibility improvements can be made by omitting the non-essential stability sides.

The design of the portion of the shoe sole directly underneath the foot

5   shown in Fig. 48 allows for unobstructed natural inversion/eversion motion of the calcaneus by providing maximum shoe sole flexibility particularly between the base of the calcaneus 125 (heel) and the metatarsal heads 126 (forefoot) along an axis 124. An unnatural torsion occurs about that axis if flexibility is insufficient so that a conventional shoe sole interferes with the inversion/eversion motion by

10 restraining it. The object of the design is to allow the relatively more mobile (in inversion and eversion) calcaneus to articulate freely and independently from the relatively more fixed forefoot instead of the fixed or fused structure or lack of stable structure between the two in conventional designs. In a sense, freely articulating joints are created in the shoe sole that parallel those of the foot. The

15 design is to remove nearly all of the shoe sole material between the heel and the forefoot, except under one of the previously described essential structural support elements, the base of the fifth metatarsal 97. An optional support for the main longitudinal arch 121 may also be retained for runners with substantial foot pronation, although it would not be necessary for many runners.

20 The forefoot can be subdivided (not shown) into its component essential structural support and propulsion elements, the individual heads of the metatarsal and the heads of the distal phalanges, so that each major articulating joint set of the foot is paralleled by a freely articulating shoe sole support propulsion element,

an anthropomorphic design; various aggregations of the subdivision are also possible.

The design in Fig. 48 features an enlarged structural support at the base of the fifth metatarsal in order to include the cuboid, which can also come into contact with the ground under arch compression in some individuals. In addition, the design can provide general side support in the heel area, as in Fig. 48E or alternatively can carefully orient the stability sides in the heel area to the exact positions of the lateral calcaneal tuberosity 108 and the main base of the calcaneus 109, as in Fig. 48E' (showing heel area only of the right foot). Figs. 48A-48D show frontal plane cross sections of the left shoe and Fig. 48E shows a bottom view of the right foot, with flexibility axes 122, 124, 111, 112 and 113 indicated. Fig. 48F shows a sagittal plane cross section showing the structural elements joined by a very thin and relatively soft upper midsole layer. Figs. 48G and 48H show similar cross sections with slightly different designs featuring durable fabric only (slip-lasted shoe), or a structurally sound arch design, respectively. Fig. 48I shows a side medial view of the shoe sole.

Fig. 48J shows a simple interim or low cost construction for the articulating shoe sole support element 95 for the heel (showing the heel area only of the right foot); while it is most critical and effective for the heel support element 95, it can also be used with the other elements, such as the base of the fifth metatarsal 97 and the long arch 121. The heel sole element 95 shown can be a single flexible layer or a lamination of layers. When cut from a flat sheet or molded in the general pattern shown, the outer edges can be easily bent to follow

the contours of the foot, particularly the sides. The shape shown allows a flat or

slightly rounded heel element 95 to be attached to a highly rounded shoe upper or

very thin upper sole layer like that shown in Fig. 48F. Thus, a very simple

construction technique can yield a highly sophisticated shoe sole design. The size

5   of the center section 119 can be small to conform to a fully or nearly fully

rounded design or larger to conform to a rounded sides design, where there is a

large flattened sole area under the heel. The flexibility is provided by the

removed diagonal sections, the exact proportion of size and shape can vary.

Fig. 49 shows use of the theoretically ideal stability plane concept to

10   provide natural stability in negative heel shoe soles that are less thick in the heel

area than in the rest of the shoe sole; specifically, a negative heel version of the

naturally rounded sides conforming to a load-bearing foot design shown in Fig.

14 above.

Figs. 49A, 49B, and 49C represent frontal plane cross sections taken

15   along the forefoot, at the base of the fifth metatarsal, and at the heel, thus

illustrating that the shoe sole thickness is constant at each frontal plane cross

section, even though that thickness varies from front to back, due to the sagittal

plane variation 40 (shown hatched) causing a lower heel than forefoot, and that

the thickness of the naturally rounded sides is equal to the shoe sole thickness in

20   each Fig. 49A-49C cross-section. Moreover, in Fig. 49D, a horizontal plane

overview or top view of the left foot sole, it can be seen that the horizontal

contour of the sole follows the preferred principle in matching, as nearly as

practical, the rough footprint of the load-bearing foot sole.

The abbreviation of essential structural support elements can also be applied to negative heel shoe soles such as that shown in Fig. 49 and dramatically improves their flexibility. Negative heel shoe soles such as Fig. 49 can also be modified by inclusion of aspects of the other embodiments disclosed herein.

Fig. 50 shows, in Figs. 50A-50D, possible sagittal plane shoe sole thickness variations for negative heel shoes. The hatched areas indicate the forefoot lift or wedge 40. At each point along the shoe soles seen in sagittal plane cross sections, the thickness varies as shown in Figs. 50A-50D, while the thickness of the naturally rounded sides 28a, as measured in the frontal plane, equal and therefore vary directly with those sagittal plane thickness variations. Fig. 50A shows the same embodiment as Fig. 49.

Fig. 51 shows the application of the theoretically ideal stability plane concept in flat shoe soles that have no heel lift to provide for natural stability, maintaining the same thickness throughout, with rounded stability sides abbreviated to only essential structural support elements to provide the shoe sole with natural flexibility paralleling that of the human foot.

Figs. 51A, 51B, and 51C represent frontal plane cross-sections taken along the forefoot, at the base of the fifth metatarsal, and at the heel, thus illustrating that the shoe sole thickness is constant at each frontal plane cross section, while constant in the sagittal plane from front to back, so that the heel and forefoot have the same shoe sole thickness, and that the thickness of the naturally rounded sides is equal to the shoe sole thickness in each Fig. 51A-51C cross-section. Moreover, in Fig. 51C, a horizontal plane overview or top view of

the left foot sole, it can be seen that the horizontal contour of the sole follows the preferred principle in matching, as nearly as practical, the rough footprint of the load-bearing foot sole. Fig. 51E, a sagittal plane cross section, shows that shoe sole thickness is constant in that plane.

5   Fig. 51 shows the applicant's prior invention of contour sides abbreviated to essential structural elements, as applied to a flat shoe sole. Fig. 51 shows the horizontal plane top view of fully rounded shoe sole of the left foot abbreviated along the sides to only essential structural support and propulsion elements (shown hatched). Shoe sole material density can be increased in the

10   unabbreviated essential elements to compensate for increased pressure loading there. The essential structural support elements are the base and lateral tuberosity of the calcaneus 95, the heads of the metatarsals 96, and base of the fifth metatarsal 97. They must be supported both underneath and to the outside for stability. The essential propulsion element is the head of the first distal phalange

15   98.

The medial (inside) and lateral (outside) sides supporting the base and lateral tuberosity of the calcaneus are shown in Fig. 51 oriented in a conventional way along the longitudinal axis of the shoe sole, in order to provide direct structural support to the base and lateral tuberosity of the calcaneus, but can be

20   located also along either side of the horizontal plane subtalar ankle joint axis . Fig. 51 shows that the naturally rounded stability sides need not be used except in the identified essential areas. Weight savings and flexibility improvements can be made by omitting the non-essential stability sides. A horizontal plane bottom

view (not shown) of Fig. 51 would be the exact reciprocal or converse of Fig. 51 with the peaks and valleys contours exactly reversed.

Flat shoe soles such as Fig. 51 can also be modified by inclusion of various aspects of the other embodiments disclosed herein.

5   Central midsole section 188 and upper section 187 in Fig. 12 must fulfill a cushioning function which frequently calls for relatively soft midsole material. The shoe sole thickness effectively decreases in the Fig. 12 embodiment when the soft central section is deformed under weight-bearing pressure to a greater extent than the relatively firmer sides.

10   In order to control this effect, it is necessary to measure it. What is required is a methodology of measuring a portion of a static shoe sole at rest that will indicate the resultant thickness under deformation. A simple approach is to take the actual least distance thickness at any point and multiply it times a factor for deformation or "give", which is typically measured in durometers (on Shore A

15   scale), to get a resulting thickness under a standard deformation load. Assuming a linear relationship (which can be adjusted empirically in practice), this method would mean that a shoe sole midsection of 1 inch thickness and a fairly soft 30 durometer would be roughly functionally equivalent under equivalent load-bearing deformation to a shoe midsole section of 1/2 inch and a relatively hard 60

20   durometer; they would both equal a factor of 30 inch-durometers. The exact methodology can be changed or improved empirically, but the basic point is that static shoe sole thickness needs to have a dynamic equivalent under equivalent loads, depending on the density of the shoe sole material.

Since the Theoretically Ideal Stability Plane 51 has already been generally

defined in part as having a constant frontal plane thickness and preferring a

uniform material density to avoid arbitrarily altering natural foot motion, it is

logical to develop a non-static definition that includes compensation for shoe sole

5   material density. The Theoretically Ideal Stability Plane defined in dynamic

terms would alter constant thickness to a constant multiplication product of

thickness times density.

Using this restated definition of the Theoretically Ideal Stability Plane

presents an interesting design possibility: the somewhat extended width of shoe

10   sole sides that are required under the static definition of the Theoretically Ideal

Stability Plane could be reduced by using a higher density midsole material in the

naturally rounded sides.

Fig. 52 shows, in frontal plane cross section at the heel, the use of a high

density (d') midsole material on the naturally rounded sides and a low density (d)

15   midsole material everywhere else to reduce side width. To illustrate the principle,

it was assumed in Fig. 52 that density (d') is twice that of density (d), so the effect

is somewhat exaggerated, but the basic point is that shoe sole width can be

reduced significantly by using the Theoretically Ideal Stability Plane with a

definition of thickness that compensates for dynamic force loads. In the Fig. 52

20   example, about one fourth of an inch in width on each side is saved under the

revised definition, for a total width reduction of one half inch, while rough

functional equivalency should be maintained, as if the frontal plane thickness and

density were each unchanging.

As shown in Fig. 52, the boundary between sections of different density is indicated by the line 45 and the line 51' parallel to 51 at half the distance from the outer surface of the foot 29.

Note that the design in Fig. 52 uses low density midsole material, which is effective for cushioning, throughout that portion of the shoe sole that would be directly load-bearing from roughly 10 degrees of inversion to roughly 10 degrees eversion, the normal range of maximum motion during athletics; the higher density midsole material is tapered in from roughly 10 degrees to 30 degrees on both sides, at which ranges cushioning is less critical than providing stabilizing support.

Fig. 53 show the footprints of the natural barefoot sole and shoe sole. The footprints are the areas of contact between the bottom of the foot or shoe sole and the flat, horizontal plane of the ground, under normal body weight-bearing conditions. Fig. 53A shows a typical right footprint outline 37 when the foot is upright with its sole flat on the ground.

Fig. 53B shows the footprint outline 17 of the same foot when tilted out 20 degrees to about its normal limit; this footprint corresponds to the position of the foot shown in Fig. 43 above. Critical to the inherent natural stability of the barefoot is that the area of contact between the heel and the ground is virtually unchanged, and the area under the base of the fifth metatarsal and cuboid is narrowed only slightly. Consequently, the barefoot maintains a wide base of support even when tilted to its most extreme lateral position.

The major difference shown in Fig. 53B is clearly in the forefoot, where all of the heads of the first through fourth metatarsals and their corresponding phalanges no longer make contact with the ground. Of the forefoot, only the head of the fifth metatarsal continues to make contact with the ground, as does its corresponding phalange, although the phalange does so only slightly. The forefoot motion of the forefoot is relatively great compared to that of the heel.

Fig. 53C shows a shoe sole print outline of a shoe sole of the same size as the bare foot in Figs. 53A & 53B when tilted out 20 degrees to the same position as Fig 53B; this position of the shoe sole corresponds to that shown in Fig. 44 above. The shoe sole maintains only a very narrow bottom edge in contact with the ground, an area of contact many times less than the bare foot.

Fig. 54 shows two footprints like footprint 37 in Fig. 53A of a bare foot upright and footprint 17 in Fig. 53B of a bare foot tilted out 20 degrees, but showing also their actual relative positions to each other as the foot rolls outward from upright to tilted out 20 degrees. The bare foot tilted footprint is shown hatched. The position of tilted footprint 17 so far to the outside of upright footprint 37 demonstrates the requirement for greater shoe sole width on the lateral side of the shoe to keep the foot from simply rolling off of the shoe sole; this problem is in addition to the inherent problem caused by the rigidity of the conventional shoe sole. The footprints are of a high arched foot.

Fig. 55 shows the applicant's invention of shoe sole with a lateral stability sipe 11 in the form of a vertical slit. The lateral stability sipe allows the shoe sole to flex in a manner that parallels the foot sole, as seen is Figs. 53 & 54. The lateral

stability sipe 11 allows the forefoot of the shoe sole to pivot off the ground with

the wear's forefoot when the wearer's foot rolls out laterally. At the same time, it

allows the remaining shoe sole to remain flat on the ground under the wearer's

load-bearing tilted footprint 17 in order to provide a firm and natural base of

5   structural support to the wearer's heel, his fifth metatarsal base and head, as well

as cuboid and fifth phalange and associated softer tissues. In this way, the lateral

stability sipe provides the wearer of even a conventional shoe sole with lateral

stability like that of the bare foot. All types of shoes can be distinctly improved

with this invention, even women's high heeled shoes.

10   With the lateral stability sipe, the natural supination of the foot, which is

its outward rotation during load-bearing, can occur with greatly reduced

obstruction. The functional effect is analogous to providing a car with

independent suspension, with the axis aligned correctly. At the same time, the

principle load-bearing structures of the foot are firmly supported with no sipes

15   directly underneath.

Fig. 55A is a top view of a conventional shoe sole with a corresponding

outline of the wearer's footprint superimposed on it to identify the position of the

lateral stability sipe 11, which is fixed relative to the wearer's foot, since it

removes the obstruction to the foot's natural lateral flexibility caused by the

20   conventional shoe sole.

With the lateral stability sipe 11 in the form of a vertical slit, when the

foot sole is upright and flat, the shoe sole provides firm structural support as if the

sipe were not there. No rotation beyond the flat position is possible with a sipe in

the form of a slit, since the shoe sole on each side of the slit prevents further motion.

Many variations of the lateral stability sipe 11 are possible to provide the same unique functional goal of providing shoe sole flexibility along the general axis shown in Fig. 55. For example, the slit can be of various depths depending on the flexibility of the shoe sole material used; the depth can be entirely through the shoe sole, so long as some flexible material acts as a joining hinge, like the cloth of a fully lasted shoe, which covers the bottom of the foot sole, as well as the sides. The slits can be multiple, in parallel or askew. They can be offset from vertical. They can be straight lines, jagged lines, curved lines or discontinuous lines.

Although slits are preferred, other sipe forms such as channels or variations in material densities as described above can also be used, though many such forms will allow varying degrees of further pronation rotation beyond the flat position, which may not be desirable, at least for some categories of runners. Other methods in the existing art can be used to provide flexibility in the shoe sole similar to that provided by the lateral stability sipe along the axis shown in Fig. 55.

The axis shown in Fig. 55 can also vary somewhat in the horizontal plane. For example, the footprint outline 37 shown in Fig. 55 is positioned to support the heel of a high arched foot; for a low arched foot tending toward excessive pronation, the medial origin 14 of the lateral stability sipe would be moved forward to accommodate the more inward or medial position of pronator's heel.

The axis position can also be varied for a corrective purpose tailored to the individual or category of individual: the axis can be moved toward the heel of a rigid, high arched foot to facilitate pronation and flexibility, and the axis can be moved away from the heel of a flexible, low arched foot to increase support and

5   reduce pronation.

It should be noted that various forms of firm heel counters and motion control devices in common use can interfere with the use of the lateral stability sipe by obstructing motion along its axis; therefore, the use of such heel counters and motion control devices should be avoided. The lateral stability sipe may also

10   compensate for shoe heel-induced outward knee cant.

Fig. 55B is a cross section of the shoe sole 22 with lateral stability sipe 11. The shoe sole thickness is constant but could vary as do many conventional and unconventional shoe soles known to the art. The shoe sole could be conventionally flat like the ground or conform to the shape of the wearer's foot.

15   Fig. 55C is a top view like Fig. 55A, but showing the print of the shoe sole with a lateral stability sipe when the shoe sole is tilted outward 20 degrees, so that the forefoot of the shoe sole is not longer in contact with the ground, while the heel and the lateral section do remain flat on the ground.

Fig. 56 shows a conventional shoe sole with a medial stability sipe 12 that

20   is like the lateral sipe 11, but with a purpose of providing increased medial or pronation stability instead of lateral stability; the head of the first metatarsal and the first phalange are included with the heel to form a medial support section inside of a flexibility axis defined by the medial stability sipe 12. The medial

stability sipe 12 can be used alone, as shown, or together with the lateral stability

sipe 11, which is not shown.

Fig. 57 shows footprints 37 and 17, like Fig. 54, of a right barefoot

upright and tilted out 20 degrees, showing the actual relative positions to each

5   other as a low arched foot rolls outward from upright to tilted out 20 degrees. The

low arched foot is particularly noteworthy because it exhibits a wider range of

motion than the Fig. 54 high arched foot, so the 20 degree lateral tilt footprint 17

is farther to the outside of upright footprint 37. In addition, the low arched foot

pronates inward to inner footprint borders 18; the hatched area 19 is the increased

10   area of the footprint due to the pronation, whereas the hatched area 16 is the

decreased area due to pronation.

In Fig. 57, the lateral stability sipe 11 is clearly located on the shoe sole

along the inner margin of the lateral footprint 17 superimposed on top of the shoe

sole and is straight to maximize ease of flexibility. The basic Fig. 57 design can

15   of course also be used without the lateral stability sipe 11.

A shoe sole of extreme width is necessitated by the common foot

tendency toward excessive pronation, as shown in Fig. 57, in order to provide

structural support for the full range of natural foot motion, including both

pronation and supination. Extremely wide shoe soles are most practical if the

20   sides of the shoe sole are not flat as is conventional but rather are bent up to

conform to the natural shape of the shoe wearer's foot sole.

Figures 58A-58D shows the use of flexible and relatively inelastic fiber in

the form of strands, woven or unwoven (such as pressed sheets), embedded in

midsole and bottom sole material. Optimally, the fiber strands parallel (at least roughly) the plane surface of the wearer's foot sole in the naturally rounded design in Figs. 58A-58C and parallel the flat ground in Fig. 58D, which shows a section of conventional, non-rounded shoe sole. Fiber orientations at an angle to this

5 parallel position will still provide improvement over conventional soles without fiber reinforcement, particularly if the angle is relatively small; however, very large angles or omni-directionality of the fibers will result in increased rigidity or increased softness.

This preferred orientation of the fiber strands, parallel to the plane of the

10 wearer's foot sole, allows for the shoe sole to deform to flatten in parallel with the natural flattening of the foot sole under pressure. At the same time, the tensile strength of the fibers resist the downward pressure of body weight that would normally squeeze the shoe sole material to the sides, so that the side walls of the shoe sole will not bulge out (or will do so less so). The result is a shoe sole

15 material that is both flexible and firm. This unique combination of functional traits is in marked contrast to conventional shoe sole materials in which increased flexibility unavoidably causes increased softness and increased firmness also increases rigidity. Fig. 58A is a modification of Fig. 5A, Fig. 58B is Fig. 6 modified and Fig. 58C is Fig. 7 modified. The position of the fibers shown would

20 be the same even if the shoe sole material is made of one uniform material or of other layers than those shown here.

The use of the fiber strands, particularly when woven, provides protection against penetration by sharp objects, much like the fiber in radial automobile tires.

The fiber can be of any size, either individually or in combination to form strands; and of any material with the properties of relative inelasticity (to resist tension forces) and flexibility. The strands of fiber can be short or long, continuous or discontinuous. The fibers facilitate the capability of any shoe sole using them to

5   be flexible but hard under pressure, like the foot sole.

It should also be noted that the fibers used in both the cover of insoles and the Dellinger Web is knit or loosely braided rather than woven, which is not preferred, since such fiber strands are designed to stretch under tensile pressure so that their ability to resist sideways deformation would be greatly reduced

10   compared to non-knit fiber strands that are individually (or in twisted groups of yarn) woven or pressed into sheets.

Figures 59A-59D are Figs. 9A-D modified to show the use of flexible inelastic fiber or fiber strands, woven or unwoven (such as pressed) to make an embedded capsule shell that surrounds the cushioning compartment 161

15   containing a pressure-transmitting medium like gas, gel, or liquid. The fibrous capsule shell could also directly envelope the surface of the cushioning compartment, which is easier to construct, especially during assembly. Fig. 59E is a figure showing a fibrous capsule shell 191 that directly envelopes the surface of a cushioning compartment 161; the shoe sole structure is not fully rounded,

20   like Fig. 59A, but naturally rounded, and has a flat middle portion corresponding to the flattened portion of a wearer's load-bearing foot sole.

Figure 59F shows a unique combination of the Figs. 9 & 10 design above. The upper surface 165 and lower surface 166 contain the cushioning

compartment 161, which is subdivided into two parts. The lower half of the cushioning compartment 161 is both structured and functions like the compartment shown in Fig. 9 above. The upper half is similar to Fig. 10 above but subdivided into chambers 192 that are more geometrically regular so that

5   construction is simpler; the structure of the chambers 192 can be of honeycombed in structure. The advantage of this design is that it copies more closely than the Fig. 9 design the actual structure of the wearer's foot sole, while being much more simple to construct than the Fig. 10 design. Like the wearer's foot sole, the Fig. 59F design would be relative soft and flexible in the lower half of the chamber

10   161, but firmer and more protective in the upper half, where the mini-chambers 192 would stiffen quickly under load-bearing pressure. Other multi-level arrangements are also possible.

Figures 60A-60D show the use of embedded flexible inelastic fiber or fiber strands, woven or unwoven, in various embodiments similar those shown in

15   Figs. 58A-58D. Fig. 60E is a figure showing a frontal plane cross section of a fibrous capsule shell 191 that directly envelopes the surface of the midsole section 188.

Figure 61C compares the footprint made by a conventional shoe 35 with the relative positions of the wearer's right foot sole in the maximum supination

20   position 37a and the maximum pronation position 37b. Figure 61C reinforces the indication that more relative sideways motion occurs in the forefoot and midtarsal areas, than in the heel area.

As shown in Fig. 61C, at the extreme limit of supination and pronation foot motion, the base of the calcaneus 109 and the lateral calcaneal tuberosity 108 roll slightly off the sides of the shoe sole outer boundary 35. However, at the same extreme limit of supination, the base of the fifth metatarsal 97 and the head

5   of the fifth metatarsal 94 and the fifth distal phalange 93 all have rolled completely off the outer boundary 35 of the shoe sole.

Figure 61D shows an overhead perspective of the actual bone structures of the foot.

Figure 62 is similar to Fig. 57 above, in that it shows a shoe sole that

10   covers the full range of motion of the wearer's right foot sole, with or without a sipe 11. However, while covering that full range of motion, it is possible to abbreviate the rounded sides of the shoe sole to only the essential structural and propulsion elements of the foot sole, as previously discussed herein.

Figure 63 shows an electronic image of the relative forces present at the

15   different areas of the bare foot sole when at the maximum supination position shown as 37a in Figure 62 above; the forces were measured during a standing simulation of the most common ankle spraining position. The maximum force was focused at the head of the fifth metatarsal and the second highest force was focused at the base of the fifth metatarsal. Forces in the heel area were

20   substantially less overall and less focused at any specific point.

Fig. 63 indicates that, among the essential structural support and propulsion elements shown in Figure 40 above, there are relative degrees of importance. In terms of preventing ankle sprains, the most common athletic

injury (about two-thirds occur in the extreme supination position 37a shown in

Fig. 62), Fig. 63 indicates that the head of the fifth metatarsal 94 is the most

critical single area that must be supported by a shoe sole in order to maintain

barefoot-like lateral stability. Fig. 63 indicates that the base of the fifth metatarsal

5   97 is very close to being as important. Generally, the base and the head of the

fifth metatarsal are completely unsupported by a conventional shoe sole.

Figs. 64A-64B demonstrate a variation in the theoretically ideal stability

plane. In previously described embodiments, the inner surface of the theoretically

ideal stability plane conforms to the shape of the wearer's foot, especially its

10   sides, so that the inner surface of the applicant's shoe sole invention conforms to

the outer surface of the wearer's foot sole, especially it sides, when measured in

frontal plane or transverse plane cross sections. For illustration purposes, the

right side of Fig. 64 explicitly illustrates such an embodiment.

The right side of Fig. 64 includes an upper shoe sole surface that is

15   complementary to the shape of all or a portion the wearer's foot sole. In addition,

this application describes shoe rounded sole side designs wherein the inner

surface of the theoretically ideal stability plane lies at some point between

conforming or complementary to the shape of the wearer's foot sole, that is --

roughly paralleling the foot sole including its side -- and paralleling the flat

20   ground; that inner surface of the theoretically ideal stability plane becomes load-

bearing in contact with the foot sole during foot inversion and eversion, which is

normal sideways or lateral motion.

Again, for illustration purposes, the left side of Fig. 64B describes shoe

sole side designs wherein the lower surface of the theoretically ideal stability

plane, which equates to the load-bearing surface of the bottom or outer shoe sole,

of the shoe sole side portions is above the plane of the underneath portion of the

5   shoe sole, when measured in frontal or transverse plane cross sections; that lower

surface of the theoretically ideal stability plane becomes load-bearing in contact

with the ground during foot inversion and eversion, which is normal sideways or

lateral motion.

Although the inventions described in this application may in some

10   instances be less than optimal, they nonetheless distinguish over all prior art and

still do provide a significant stability improvement over existing footwear and

thus provide significantly increased injury prevention benefit compared to

existing footwear.

Fig. 65 provides a means to measure the rounded shoe sole sides incorpo-

15   rated in the applicant's inventions described above. Fig. 65 correlates the height

or extent of the rounded side portions of the shoe sole with a precise angular

measurement from zero to 180 degrees. That angular measurement corresponds

roughly with the support for sideways tilting provided by the rounded shoe sole

sides of any angular amount from zero degrees to 180 degrees, at least for such

20   rounded sides proximate to any one or more or all of the essential stability or

propulsion structures of the foot, as defined above. The rounded shoe sole sides

as described in this application can have any angular measurement from zero

degrees to 180 degrees.

Figs. 66A-66F, Fig.67A-67E and Fig. 68 describe shoe sole structural inventions that are formed with an upper surface to conform, or at least be complementary, to the all or most or at least part of the shape of the wearer's foot sole, whether under a body weight load or unloaded, but without rounded stability sides as defined by the applicant. As such, Figs. 66-68 are similar to Figs. 38-40 above, but without the rounded stability sides at the essential structural support and propulsion elements, which are the base and lateral tuberosity of the calcaneus, the heads of the first and fifth metatarsals, the base of the fifth metatarsal, and the first distal phalange, and with shoe sole rounded side thickness variations, as measured in frontal plane cross sections as defined in this and earlier applications.

Figs. 66A-66F, Fig. 67A-67E, and Fig. 68, like the many other variations of the applicant's naturally rounded design described in this application, show a shoe sole invention wherein both the upper, foot sole-contacting surface of the shoe sole and the bottom, ground-contacting surface of the shoe sole mirror the contours of the bottom surface of the wearer's foot sole, forming in effect a flexible three dimensional mirror of the load-bearing portions of that foot sole when bare.

The shoe sole shown in Figs. 66-68 preferably include an insole layer, a midsole layer, and bottom sole layer, and variation in the thickness of the shoe sole, as measured in sagittal plane cross sections, like the heel lift common to most shoes, as well as a shoe upper.

Figure 69A-69D shows the implications of relative difference in range of motions between forefoot, midtarsal, and heel areas. Fig. 69A-D is a modification of Fig. 33 above, with the left side of the figures showing the required range of motion for each area.

5   Fig. 69A shows a cross section of the forefoot area and therefore on the left side shows the highest rounded sides (compared to the thickness of the shoe sole in the forefoot area) to accommodate the greater forefoot range of motion. The rounded side is sufficiently high to support the entire range of motion of the wearer's foot sole. Note that the sock liner or insole 2 is shown.

10   Fig. 69B shows a cross section of the midtarsal area at about the base of the fifth metatarsal, which has somewhat less range of motion and therefore the rounded sides are not as high (compared to the thickness of the shoe sole at the midtarsal area). Fig. 69C shows a cross section of the heel area, where the range of motion is the least, so the height of the rounded sides is relatively least of the three general areas (when compared to the thickness of the shoe sole in the heel area).

15

Each of the three general areas, forefoot, midtarsal and heel, have rounded sides that differ relative to the high of those sides compared to the thickness of the shoe sole in the same area. At the same time, note that the absolute height of the rounded sides is about the same for all three areas and the contours have a similar outward appearance, even though the actual structure differences are quite significant as shown in cross section.

In addition, the rounded sides shown in Fig. 69A-D can be abbreviated to support only those essential structural support and propulsion elements identified in Fig. 40 above. The essential structural support elements are the base and lateral tuberosity of the calcaneus 95, the heads of the metatarsals 96, and the base

5 of the fifth metatarsal 97. The essential propulsion element is the head of the first distal phalange 98.

Figure 70 shows a similar view of a bottom sole structure 149, but with no side sections. The areas under the forefoot 126, heel 125, and base of the fifth metatarsal 97 would not be glued or attached firmly, while the other area (or most

10 of it) would be glued or firmly attached. Fig. 70 also shows a modification of the outer periphery of the convention shoe sole 36: the typical indentation at the base of the fifth metatarsal is removed, replaced by a fairly straight line 100.

Figure 71 shows a similar structure to Fig. 70, but with only the section under the forefoot 126 unglued or not firmly attached; the rest of the bottom sole

15 149 (or most of it) would be glued or firmly attached.

Figures 72G-72H show shoe soles with only one or more, but not all, of the essential stability elements (the use of all of which is still preferred) but which, based on Fig. 63, still represent major stability improvements over existing footwear. This approach of abbreviating structural support to a few

20 elements has the economic advantage of being capable of construction using conventional flat sheets of shoe sole material, since the individual elements can be bent up to the contour of the wearer's foot with reasonable accuracy and without difficulty. Whereas a continuous naturally rounded side that extends all

of, or even a significant portion of, the way around the wearer's foot sole would

buckle partially since a flat surface cannot be accurately fitted to a rounded

surface; hence, injection molding is required for accuracy.

The features of Figs. 72G-72H can be used in combination with the

5   designs shown in this application. Further, various combinations of abbreviated

structural support elements may be utilized other than those specifically

illustrated in the figures.

Figure 72G shows a shoe sole combining the additional stability

corrections 96a, 96b, and 98a supporting the first and fifth metatarsal heads and

10   distal phalange heads. The dashed line 98a' represents a symmetrical optional

stability addition on the lateral side for the heads of the second through fifth distal

phalanges, which are less important for stability.

Figure 72H shows a shoe sole with symmetrical stability additions 96a

and 96b. Besides being a major improvement in stability over existing footwear,

15   this design is aesthetically pleasing and could even be used with high heel type

shoes, especially those for women, but also any other form of footwear where

there is a desire to retain relatively conventional looks or where the shear height

of the heel or heel lift precludes stability side corrections at the heel or the base of

the fifth metatarsal because of the required extreme thickness of the sides. This

20   approach can also be used where it is desirable to leave the heel area

conventional, since providing both firmness and flexibility in the heel is more

difficult that in other areas of the shoe sole since the shoe sole thickness is usually

much greater there; consequently, it is easier, less expensive in terms of change,

and less of a risk in departing from well understood prior art just to provide

additional stability corrections to the forefoot and/or base of the fifth metatarsal

area only.

Since the shoe sole thickness of the forefoot can be kept relatively thin,

5   even with very high heels, the additional stability corrections can be kept

relatively inconspicuous. They can even be extended beyond the load-bearing

range of motion of the wearer's foot sole, even to wrap all the way around the

upper portion of the foot in a strictly ornamental way (although they can also play

a part in the shoe upper's structure), as a modification of the strap, for example,

10   often seen on conventional loafers.

Figs. 73A-73D show close-up cross sections of shoe soles modified with

the applicant's inventions for deformation sipes.

Fig. 73A shows a cross section of a design with deformation sipes in the

form of channels, but with most of the channels filled with a material 170 flexible

15   enough that it still allows the shoe sole to deform like the human foot. Fig. 73B

shows a similar cross section with the channel sipes extending completely

through the shoe sole, but with the intervening spaces also filled with a flexible

material 170 like Fig 73A; a flexible connecting top layer 123 can also be used,

but is not shown. The relative size and shape of the sipes can vary almost

20   infinitely. The relative proportion of flexible material 170 can vary, filling all or

nearly all of the sipes, or only a small portion, and can vary between sipes in a

consistent or even random pattern. As before, the exact structure of the sipes and

filler material 170 can vary widely and still provide the same benefit, though

some variations will be more effective than others. Besides the flexible connecting utility of the filler material 170, it also serves to keep out pebbles and other debris that can be caught in the sipes, allowing relatively normal bottom sole tread patterns to be created.

5   Fig. 73C shows a similar cross section of a design with deformation sipes in the form of channels that penetrate the shoe sole completely and are connected by a flexible material 170 which does not reach the upper surface 30 of the rounded shoe sole 28. Such an approach creates can create and upper shoe sole surface similar to that of the trademarked Maseur sandals, but one where the

10   relative positions of the various sections of the upper surface of the shoe sole will vary between each other as the shoe sole bends up or down to conform to the natural deformation of the foot. The shape of the channels should be such that the resultant shape of the shoe sole sections would be similar but rounded; in fact, like the Maseur sandals, cylindrical with a rounded or beveled upper surface is

15   probably optimal. The relative position of the flexible connecting material 170 can vary widely and still provide the essential benefit. Preferably, the attachment of the shoe uppers would be to the upper surface of the flexible connecting material 170.

      A benefit of the Fig. 73C design is that the resulting upper surface 30 of

20   the shoe sole can change relative to the surface of the foot sole due to natural deformation during normal foot motion. The relative motion makes practical the direct contact between shoe sole and foot sole without intervening insoles or socks, even in an athletic shoe. This constant motion between the two surfaces

allows the upper surface of the shoe sole to be roughened to stimulate the

development of tough calluses (called a "Seri boot"), as described at the end of

Fig. 10 above, without creating points of irritation from constant, unrelieved

rubbing of exactly the same corresponding shoe sole and foot sole points of

5   contact.

Fig. 73C shows a similar cross section of a design with deformation sipes

in the form of angled channels in roughly and inverted V shape. Such a structure

allows deformation bending freely both up and down; in contrast deformation

slits can only be bent up and channels with parallel side walls 151 generally offer

10   only a limited range of downward motion. The Fig. 73D angled channels would

be particularly useful in the forefoot area to allow the shoe sole to conform to the

natural contour of the toes, which curl up and then down. As before, the exact

structure of the angle channels can vary widely and still provide the same benefit,

though some variations will be more effective than others. Finally, though not

15   shown, deformation slits can be aligned above deformation channels, in a sense

continuing the channel in circumscribed form.

Figure 74 shows sagittal plane shoe sole thickness variations, such as heel

lifts 38 and forefoot lifts 40, and how the rounded sides 28a equal and therefore

vary with those varying thicknesses, as discussed in connection with Figure 31.

20   Fig. 75 shows, in Figs. 75A-75C, a method, known from the prior art, for

assembling the midsole shoe sole structure of the present invention, showing in

Figure 75C the general concept of inserting the removable midsole insert 145 into

the shoe upper and sole combination in the same very simple manner as an

intended wearer inserts his foot into the shoe upper and sole combination. Figures 75A and 75B show a similar insertion method for the bottom sole 149.

The combinations of the many elements the applicant's invention introduced in the preceding figures are shown because those embodiments are

5 considered to be at least among the most useful. However, many other useful combinations embodiments are also clearly possible, but cannot be shown simply because of the impossibility of showing them all while maintaining a reasonable brevity and conciseness in what is already an unavoidably long description due to the inherently highly interconnected nature of the inventions shown herein, each

10 of which can operate independently or as part of a combination of others.

Therefore, any combination that is not explicitly described above is implicit in the overall invention of this application and, consequently, any part of any of the preceding Figures 1-75 and/or textual specification can be combined with any other part of any one or more other of the Figures 1-75 and/or textual

15 specification of this application to make new and useful improvements over the existing art.

In addition, any unique new part of any of the preceding Figures 1-75 and/or associated textual specification can be considered by itself alone as an individual improvement over the existing art.

20 The foregoing shoe designs meet the objectives of this invention as stated above. However, it will clearly be understood by those skilled in the art that the foregoing description has been made in terms of the preferred embodiments and various changes and modifications may be made without departing from the

scope of the present invention which is to be defined by the appended claims.